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SOME CONSIDERATIONS ON THE GEOGRAPHICAL PROVINCES OF THE UNITED STATES*

MARK JEFFERSON

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INTRODUCTION: MAN'S RELATION TO THE EARTH.—Our constitution allows us many aspects of geography. We have room in our membership for cartographers, a terrestrial magnetician, zoologists, botanists, geologists, physiographers, historians and travelers, yet very generally we have especial interest in those aspects of the science that concern themselves with man. We want to find applications to man for what we learn about the earth, almost above all other things.

Geographic Influences.—Man's relations to the earth are of three main sorts. First he has been guided in his migrations by the configuration of lands and seas and the relief of the earth's surface—the geographic influences in history to which some of our members have made important contributions. Perhaps it is the field of human geography that has been cultivated most profitably.

* Presidential Address delivered before the Association of American Geographers, New York Meeting, December, 1916.

Anthropogeography.—A second sort of human geography is usually called anthropogeography. It attempts to explain the character and habits of a people by their environment. This field has special perils. A great part of what has been written is vague and fanciful rather than cautious and well-based. If no other explanation of qualities is available one may always refer to the "climate."

Anthropography.—The third field has been less cultivated, but is fundamental. It studies the distribution of men over the earth as a static fact, regardless of their movements or occupation, but paying much attention to the closeness with which they occupy their region, or the density of population from place to place. The full topical name, *distribution of population-densities,* is somewhat cumbrous. As an arbitrary name *Anthropography* would have some advantages, and its etymology is quite as good as that of many accepted names. So defined, it would be primarily a descriptive science. The questions, Where are men and How many of them are there must be answered with some care before we attempt to explain the reactions of men and inanimate nature.

Population Density Maps.—*The Data.*—The data of this aspect of geography are contained or represented on the map of population densities. There is as yet no satisfactory one for the world. Those that exist are very small of scale, rarely larger than 1:80,000,000. Even on that scale they do not show good agreement. If we had a satisfactory one on a scale, say, of 1:5,000,000, it is certain that we could at once see on it the influences of rainfall, geology, physiography, and possibly temperature, as they are shown on maps already extant, with their information in considerable detail. If all these forms of environment react on man it is evident that the facts of man's distribution among them should be known in all possible detail before we study the reactions. Yet it is curious that less attention has been paid to the facts of anthropography than to the causes that ought to guide and control them. The geographic provinces of this viewpoint would be the actual groupings of men on the earth quite irrespective of any climatic or physiographic boundaries that should hypothetically control them. As a matter of fact such a study of actualities shows that some of the supposed climatic and physiographic controls are of less importance than was supposed.

Population and Precipitation in India.—As an instance may be cited the ten-millionth population map of India made by the Indian Census (1911). Comparison with the precipitation map, also made by the government of India, shows that the largest masses of very dense population do not live where the rains are heaviest, as is often supposed, but mostly in level regions of moderate or even scanty rainfall that lie under mountain slopes where the rains are heavy. It is

the irrigation of level land that supports these swarms of men, rather than heavy rainfall.

This touches what appears to be an important law in the distribution of men, that roughly level expanses of soil are almost more important for a great population than rainfall.[1]

Difficulties with Current Methods of Mapping.—But there is no agreement as to how population maps should be made. A great practical difficulty in representing the actual density of population from place to place is the very great range through which the density changes in short distances. Within twenty miles in New York we may find men living thirty to the square mile and again six hundred thousand to the mile. How shall we represent differences so extraordinary?

Cities, towns, villages, and farms seem so different as to require different treatment. It has often been the practice, therefore, in making population-density maps, to subtract the city population from the totals, with the idea that the rural inhabitants are the real occupants and users of the earth. The population maps of the United States Census have been made in this way, at least in theory. In practice, one has to have a definition of a city before he can leave it out. So far our Census bureau has had three different definitions: that cities were incorporated places whose inhabitants numbered 8,000 (definition of 1870), 4,000 (definition of 1900), and 2,500 (definition of 1910); and these appear to be rather violent and arbitrary changes of concept.

Another practical difficulty with population maps is the necessity of assuming an even distribution of the population over the whole surface of the smallest units of area for which we have data. In the United States, for instance, we divide the population of a county by its area in square miles, and pretend that the whole county has the density so ascertained. As long as the county is very small indeed in comparison with the whole map, as a Massachusetts county would be on a map of the whole United States, this serves excellently. With the counties of Utah it is less acceptable, for some of them are immense and extend from the full desert into the well-watered lands where the people actually dwell. To spread the population over the whole area is arbitrarily to increase the population in the desert and diminish it in the watered lands. Sometimes population is represented by dots, each dot standing for 1,000 or 10,000 people. But this involves putting the dots in something like correct places and with the large administrative units, like the basin of the Amazon, no one knows quite where they should go. Of course the details of boundaries between grades of population that follow county boundaries have no anthropographic meaning.

[1] Census of India, 1911, Vol. I, Pt. I, p. 18.

THE UNITY OF CITY AND COUNTRY.—But a rather extended investigation of cities and their relation to the land shows the essential unity of city and country. It is a wholly mistaken conception that attempts to separate them. Any group of close-living people who are mainly occupied with the exchange and elaboration of products rather than their direct production from the earth, whether it be a few houses at a cross-roads, a village, a town, a city or a metropolis, is a center of human activities that involve areas far beyond the immediate neighborhood. Such a group is larger or smaller according as the activities of more or fewer men are focused there. Wherever men occupy a land and go to work upon it, there appear villages and towns and cities. I am speaking of the civilized men of the world of to-day. Civilization means community life. The village and city workers are engaged in tasks that aid and prosper life in the country. Governmental functions center there and all sorts of services of agents with delegated powers, but the work is for city and country people alike. The plowing of country furrows, the reaping of country crops, the milking of country cows is of vital interest to the great city, motivated by events that happen within the city. The city is the creature of the country and cannot live without it. The city-dweller knows that without the country he would have no place from which to buy his food. He is not so well aware that without the country he would have no money to buy it with.

A great country population cannot exist to-day among civilized men without bringing cities into existence. Neither Norway nor Ecuador, on the other hand, can have a great city because they have no great country population.

THE IMPORTANCE OF A STRATEGIC POSITION FOR A CITY.—No city becomes a great one nowadays unless it has a strategic position. All cities are groups of men, in last analysis. Travel and communication have become very easy, and men in every town and city are eagerly competing for the generous rewards of modern business. Any real advantage of position of one town over another must finally bring business that way. Men do not know clearly what position is going to prove strategic, do not always recognize what the advantage of a growing town really is, but the greater growth of one city than of others around it is evidence of some geographic advantage. That city has proved that it stands in a good position to render service to its community. Geographic environment is the main determinant of size. A city of a million inhabitants must have access to a wide countryside. Thanks to modern shipping a city may now make distant lands its countryside. London is the great city not merely of England and of Great Britain, but also of the British Empire and of a good bit of the rest of the world. It has reached

out successively over the London basin, over Britain, the Empire and the world for its sustenance space.

THE NUMERICAL RELATION BETWEEN THE NUMBER OF CITIES AND THE MASS OF THE POPULATION.—There is a numerical relation between the number of cities and the mass of the population. The world contains about 355 cities of more than a hundred thousand people. We will call cities of that size Great Cities. There is one of them, then, for every five million people. But the thing is not so simple as that. We have implied as much when we said that cities were foci of human activity. Some men are very active and some do not react at all to the stimuli of civilization. Africa's seven great cities amount to one for every twenty-one million people. But many of the people of Africa are in no sort of touch with any of these cities. They are not the sort of people to create or use cities of that size. People need more and more great cities in proportion as they have higher status in the modern scheme of culture. If we reckon the relative number of great cities to each ten million people in different countries, we should have: in Australia 12, in the United Kingdom 9, in Switzerland 8, in Canada 7, in the United States 7, in Holland 7, in Germany 7, and then, after a long list of intermediate countries, in Japan 2 and in India 1. Further if we class cities of from ten to a hundred thousand as small ones we find for each ten million people: in England 123, in the United States 53, in Canada 53, and in India 37.

For the different parts of the United States the number varies from 5 for the South and Mid-west to 11 for the Northeast and 12 for the Pacific coast.

THE DEGREE OF MAN'S OCCUPATION OF THE EARTH AS EVIDENCED BY THE NUMBER AND SIZE OF CITIES.—On account of the special character of cities as foci of human activities, it will be of interest to reverse the procedure of the Census and, instead of omitting the cities, omit the country and use the cities and their size as a criterion of the degree of man's occupation of the earth. They have the great advantage for this purpose in that they may be precisely located. If we could make a great map of the world that would show in their correct location not merely the great cities, but the small ones and the little towns and villages, with some connotation of the number of people in each that could be read at a glance, without any names to confuse the effects, we should have the best representation of the actual distribution of men over the earth. The groupings of these human foci would sketch for us the actual geographic provinces of the earth, not physiographic, not geologic, not climatic nor yet political, but geographic as showing man on the actual earth in the play of varied forces.

Not only have such maps not been made, but the best maps available

mask the information they contain in various ways, so that it is as difficult to get as if intentionally concealed. Most of the data needed for such maps exist in civilized countries. Even in lands of less culture a fair approximation is possible. The value of such a map, however, has not been recognized.

As a step toward it I offer here maps of all the cities of ten thousand inhabitants or more in agricultural India, in the industrial United Kingdom, and in the United States, in nineteen graded symbols suggesting size by their own magnitude and giving some detail by their shape (Pl. II). All three maps are for the year 1910 (United Kingdom 1911); all are on the same scale of 1:15,000,000, which is seen to be pretty small even with our omission of the smaller places.

The Cities Map of the United Kingdom.—Of the British map, another impression is added on a larger scale, 1:4,300,000,[2] inasmuch as the symbols are not legible on the smaller scale. The smaller map, however, affords the proper basis for areal comparison and at least gives mass effects. The maps of India, the United States, and the United Kingdom on the same scale give at a glance an impression of the populousness of the three regions, as far as is possible with the omission of the smaller places, a much greater omission for India than for the western countries.

The Five Geographic Provinces of the British Islands.—These British towns, 542 in number, fall into five groups, which may be said to constitute, from a human point of view, the five geographic provinces of the British Islands. The groups are: the Scottish lowlands, the Newcastle coalfields, the Midlands, the South Wales coalfields, and the London basin. It is impossible to look at this map, knowing the position of the coalfields of the United Kingdom, and escape the conviction that coal is dominant in British geography.[3] Only the London basin was determined by other factors. Yet that is the great center of the kingdom and the empire. Plainly commerce avails more than coal, but it has reacted on it. It is a commerce that has been built up on the coalfield industries; and it is directed especially towards the continent of Europe. That is what its location about London signifies.

These are the five geographic provinces of the United Kingdom. They are very real. Though some of them do not appear in our geographies, they are constantly in the mouths of British men of business. They are wonderfully illuminated by a map of British coalfields. A relief map sheds sidelight by showing that Britain's

[2] Practically the same as the scale of the map in its original published form in the *Geographical Review* for Nov., 1917, and the writer's *Notes on the Geography of Europe*, Ypsilanti, Mich., 1917.

[3] Mark Jefferson: The Distribution of British Cities and the Empire. *Geogr. Rev.*, Vol. 4, 1917, pp. 387-394.

rough, mountainous country has no cities, even small ones. It appears that the only physiographic feature that attracts men in the mass is the plain. The geologic map will contribute details in the lowlands. We are interested in the vividness with which this map portrays a country according to geographic regions.

THE CITIES MAP OF INDIA.—On the map of India the cities are shown by the same method. India is an interesting country to examine in this way because the people are regarded as averse to city life. This does not mean however that the Indians live in isolated homes, but that villages rather than cities are the foci of Indian life. A peculiar feature of the great cities of India, which may be indicative of their abnormality in Indian life, is the fact that women form so small a part of their populations. In Calcutta there are but 480 women to a thousand men, in Bombay but 530. The explanation is that large numbers of men come into these cities for factory work and leave their women outside, in country villages. Nevertheless India has 33 large cities and over 600 small ones, as defined above.

The Six Groups of Indian Cities.—Again we see the cities falling into groups, of which the most striking is that of the Indo-Gangetic plain, that sweeps from the Ganges' mouth to the sources of the Indus. We may call it sub-Himalayan. It is the greatest group of people in India. The country is extremely level. It has 40 to 60 inches of rain in the eastern half, but the west has only 10 to 20, or even less. Here irrigation is possible from the well-watered slopes of the Himalayas above. "Throughout India the most thickly peopled tracts are level plains, where practically every inch of the land is fit for tillage."[4]

A second group is in Madras in the south and east, another district of very level land, in some places not well supplied with rain. The third group is Central India, including the region locally known as the Deccan. On the east it is separated from Madras by hilly country, too rough for agriculture, though it has plenty of rain. On the west it is bordered by the still rougher region of the western Ghats, which stands out on the rain map as a strip of excessive rainfall, on the city map as quite without cities.

A fourth group lies along the level plains at the foot of the western Ghats. Population maps here are misleading. As they have to bound the province by a *line,* and put it somewhere among the rougher crests, the population appears to be evenly spread from the sea into the mountains. The human boundary is not a line at all but the whole mountain region. This appears on the city map separating the cities of the coast plain from those of Central India. This region may be called the Malabar coast.

[4] Census of India, 1911, Vol. I, Pt. I, p. 27.

Fifth is the Gujarat group on the remarkable levels northwest of Bombay.

Sixth and last is the two-fold province Burma. It is a region of very rapid expansion. In the middle of the last century the population here had been nearly exterminated by tribal wars. It is probable therefore that it will grow beyond its present boundaries. In large part it is an island of lighter rainfall with excessive rains all around.

It is characteristic of the human point of view that province boundaries are regions rather than lines. Even a country is not to be regarded as a portion of the earth's surface between bounding lines but a group of people under one government together with the portion of the earth that they have in actual use. The portions of the earth not well in use constitute territories that belong to a country rather than a part of the country. Alaska is not so much a part of the United States as a territory that belongs to it. The historic conception of territories and their transformation into states of our Union confirms this view. The general basis of the transformation of territories into states is the extent to which the state is settled, as indicated by the number of its people. It is unused territory within a country that constitutes the boundaries of geographic provinces. Such are the Pennines and the Yorkshire Wolds in England, the Ghats in India, the Sierras in America, and all deserts everywhere.

THE CITIES MAP OF THE UNITED STATES.—The map of the United States on Plate II is the equivalent of the maps of the United Kingdom and of India, on the same scale and plan. It gives the same picture of man occupying the earth. The groupings of men under reaction to their environment come out at once as before. As geography transcends political boundaries, Canada is included. Nothing on the map, indeed, is more striking than the way portions of Canada unite with neighboring portions of the United States.

But in the case of the United States we are able to go farther in mapping man's occupation of the earth and include all incorporated places that have a population of over a thousand people.

Plate I shows the result, on a much larger scale (1:5,000,000), than the first three maps to allow the greater detail.

THE CONTINENTAL PROVINCES.—Three great continental provinces appear: the humid east, the arid interior, and the Pacific coast valleys.

(Footnote: In New England villages are not incorporated apart from the country district around. There we have only the population numbers for the entire township, which is always somewhat larger than the population of the village center. So the smaller places of New England are a little too large and too numerous. But this does not alter any essential feature of the map.)

The humid east is bounded on the north by the amazingly empty Archaean V in Canada, on the west by the dry high plains along the hundredth meridian.

The arid interior is bounded on the east by the dry plains, on the west by the basin deserts and the mountain country of Sierra Nevada and Cascades.

The Humid East: Subdivisions.—Subdivisions of the humid east are suggested by the very great concentration of cities along the Atlantic inner-lowland, by the close, even spacing of the cities of the mid-west, and the open, less even spacing of the cities further south. These subdivisions may be called the northeast, the mid-west, and the south. The first would correspond in a general way to the New England states and the middle Atlantic states of the Census bureau, the second to the east north-central and west north-central states of the Census and the third to the south Atlantic, the east south-central and the west south-central states. But if these provinces were used for statistical purposes, which require the use of *lines* for boundaries, the lines should not be drawn along the state boundaries, for in places one state lies in two provinces. Northern Kentucky and West Virginia belong to the mid-west rather than to the south, and most of Maryland belongs to the northeast. If administrative lines were needed in those places they should be county lines rather than state lines. So in the west. As the dry plains form the western border of the humid east, it includes only the eastern parts of the Dakotas, Nebraska, Kansas, Oklahoma, and Texas. Eastern Kansas is in the same geographic province as Missouri, western Kansas in the same one with eastern Colorado. Similarly in the far west, Okanagan, Chelan, Kititas, Yakima, and Klikitat counties in eastern Washington belong to the arid interior. The rest of the state belongs to the Pacific coast valleys, like all of Oregon except Wasco, Crook, and Klamath counties. The geographic duality of these two states is too evident to escape anyone, and economic reports should be given separately for the two sections. The boundary of the humid east on the north, against the Archaean V, is on Canadian ground, but it invades the United States again in the Adirondacks of New York and the rough country of northern Michigan and Wisconsin. This adds the eastern Canadians and their land to the humid east, regardless of politics.

The Pacific Coast Valleys.—The title Pacific coast valleys rather than states is given because the cities are so obviously valley cities. Moreover the people who live there refer to the valleys constantly. The valleys characterize the relief of the western border of America from Cape Horn to Alaska. The coast ranges, quite unlike the Appalachians, are strongly deterrent to men. The cities of the coast suggest three subdivisions. The northern one would include the Puget

Sound valley, the Willamette valley and the Rogue river country; the central one, the great valley of central California and some near coast valleys; the southern one, the Los Angeles basin, the group of irrigated settlements of southern California, containing perhaps a twentieth of the area of the state. The grouping of the cities makes this region very distinct, and it appears equally so physiographically, climatically and economically.

The Arid Interior.—In the arid interior the feature is the openness of the distribution. But there are three centers of concentration: the Colorado region extending north and south from Denver at the eastern foot of the Front Range of the Rockies; the Utah region, lying along the western foot of the Wasatch; and the Columbia-Snake river basin—it hardly seems a plateau,—lying in a great saucerlike hollow among bounding mountains. Though in three states, Washington, Idaho, and Oregon, it appears to be a distinct unit. As so often in the far west the physiography confirms the subdivision.

Summaries.—The insignificance of the Appalachians in controlling human occupation of the ground is as surprising as the sharpness of control in the west. Cities are closer together in eastern Tennessee and Kentucky than in some western parts of the same states. The empty mountain region along the boundary between West Virginia and Virginia is hardly larger than the area in central Virginia between the mountains and Richmond. Within Virginia the Shenandoah valley is a more important feature than the Appalachian ridges, and is well sprinkled with towns. Nor is western North Carolina, where occur the highest mountains east of the Mississippi, so empty of towns as the singular strip along the western border of Alabama, where there are no mountains. Always it is the valley and not the mountain that concerns men.

The greatest concentration of cities in the whole continent lies along the Atlantic inner-lowland, well apart from the mountains but humanly the most distinct region of the whole continent. The cities suggest that we continue it from beyond Washington, D. C., to Boston. No contrast on the map is so striking as that between this inner lowland and northern Maine, New Brunswick and Nova Scotia. Whatever resources geography may possess to explain the differences in man's use of New Brunswick and southern New England, the cities map brings the differences sharply before us. It will do this indeed in almost every part of the country.

The City Map of Florida.—How is it so little of the significance of city positions is shown on actual maps? It is largely due to the map-makers' abhorrence of vacant spaces. In Florida, for instance,

our city map shows the people living mainly on what Harper has called the loamy and sandy uplands of the central and northern parts of the state. The 40-mile-to-an-inch contour map of the United States in contours by the United States Geological Survey (1914) does not give the slightest impression of the human facts of the state, not even the emptiness of southern Florida. It is not an especially bad map but it is physiographic in its conception and cares not for geography. It will be worth while to look at it a little in detail. Florida has 52 incorporated places of a thousand or more people. The Survey map shows 68 places in all, but 18 of the 52 are not shown. It has therefore added 34 places of less than a thousand people and omitted 18 of more than a thousand! Some of the omitted places are of significant size: West Tampa has 8,000 people, St. Petersburg over 4,000, Lakeland and Sanford nearly 4,000, two others over 2,000, and the rest between 1,000 and 2,000. Why a third of the larger towns were omitted when twice as many smaller ones were inserted is not in all cases clear. South Jacksonville, New Augustine, and West Tampa may have been regarded as suburbs of the larger towns which it would confuse the lettering to include. Two or three towns would be hard to letter in on account of the railroads near by. Sometimes, as with Hillsboro county (now subdivided—1914—into Hillsboro and Pinella counties), it would appear that the draughtsman did not finish his work, for he put in only Tampa and Clearwater, omitting West Tampa 8,258, St. Petersburg 4,127, Plant City 2,481, Tarpon Springs 2,212, and Port Tampa, 1,343. There is plenty of room on the map for these towns. Apparently they were simply overlooked. But doubtless no numerical criterion was in the map compiler's mind and he had no list of populations before him. A third (13) of the small places inserted are county seats, which are usually regarded as of special importance. There remain 21 places small and unexplained. In De Soto county Wauchula and Punta Gorda, both above 1,000, were omitted, and there were inserted three small ones; Fort Ogden 483, Boca Grande 281 and Pine Level 262. There was plenty of room on the map here and the selection of names made adds nothing to the evenness with which names are put in on the map. In Polk county were omitted Ft. Meade 1,165, Mulberry 1,418, and Lakeland 3,719. Perhaps the most interesting of the little places added is Enterprise in Volusia county. It is a voting precinct, not incorporated. It had 590 inhabitants in 1890, dwindled to 284 in 1900 and to 188 in 1910. Probably Enterprise had some importance in 1890. There were at that date but 28 incorporated places in Florida larger than it. To-day there are hundreds of places more important. It is on the map as a survival.

SELECTING CITIES BY PRINCIPLE IN MAP-MAKING.—If the scale of a map does not allow the insertion of all places, a selection should be made governed by some principle. The draughtsman must be forbidden to even up the lettering by putting in all the places where places are scarce and omitting some where they are crowded.

Enough has been said to show the desirability of preparing place names for a map with some care and having some criterion by which to select them. None will be found so objective and so useful as the criterion of size.

It has been said that a place of 500 people in Arizona is more important than one of 5,000 in Massachusetts. It may be more important to the people within twenty miles. It is more important in its own locality, but on a map of the whole United States it is not more important. It does not stand for so much American doing and living as the Massachusetts town. In comparative views for wide areas the criterion of size is the only safe one. It is a fundamental fact in the geography of Arizona that a handful of human beings occupy it; of Massachusetts that great numbers of people live there and work there.

The "relief map" of the United States Geological Survey (1911) prints 13 place names in Arizona and 11 in Massachusetts. That is as if we were to insert all places of over 2,000 people in Arizona and all of more than 40,000 in Massachusetts. It is true that if only places of 40,000 or more were represented, Arizona would have none, nor would New Mexico, Nevada, Wyoming or Idaho. It is true that the people of these states would not like to see them without towns on a national map and that each of them has as many senators as Massachusetts or New York, that there is plenty of room to insert place names in the west, and that this is "only" a relief map. But once attention is called to it the selection of place names on this map is seen to be not well considered, and it is an excellent example of the way current maps utterly misrepresent human activities on the earth.

The only maps that give adequate expression to the location of cities and villages to-day are the large wall maps of states, such as Silas Farmer's wall map of Michigan. The Land Office map of Florida also brings out well the location of occupation, in spite of much bright coloring that confuses.

POSITIVE AND NEGATIVE PHYSIOGRAPHIC TYPES.—It has been noted how strongly actual geography discriminates between physiographic types. It regards them indeed as positive and negative. The positive types are plains, basins, or valleys where men make their homes if the rainfall or irrigation permits. The negative types are rugged mountain masses where men may not live in any general occupation of the surface. Such landscapes can never be geographic provinces, but

only boundary regions between geographic provinces. Thus in Fenneman's admirable Physiographic Divisions of the United States,[5] no. 22, the Sierra Nevada-Cascade province is geographically negative, a boundary region between the basins on the east and the valleys on the west. That is a good example of the divergence of physiographic and geographic conceptions. The physiographer's country is made of rock and dirt in varied moldings, interspersed with water. The geographer's country is a group of men living on and from the earth. The negative provinces of the physiographer are best treated by the geographer as *territory* belonging to some near country. Outside of school rooms this is universal usage. The Australian you met yesterday comes from the inhabited coastal fringe where the Australians live. If some mischance dropped him in the interior of what the school room knows as Australia, he knows he would be in the Australian desert, in Australian territory, of course, but in great danger of never reaching his home alive. The Canadian you meet to-morrow will not be a man born in the territories west of Hudson Bay, there is not one chance in millions of it, but from the St. Lawrence valley, or the southeastern coast region, probably. For political purposes boundaries must be lines, that the areas of legal jurisdiction may be defined. Humanly the boundaries are oftener regions, like the Sahara, or the southern Andes, which stand, not partly in Chile and partly in the Argentine Republic, but *between* Chile and the Argentine Republic. Indeed the linear character even of legal boundaries in mountain regions is largely theoretical. The Argentine law officers are entitled to make arrests east of the Cumbre in the Mendoza pass, and the Chileans west of it; but in fact the criminal is practically safe as soon as he enters the mountains in either country, so difficult is pursuit and discovery there.

THE LIMITATIONS IN THE USE OF PHYSIOGRAPHIC PROVINCES.—It is for this reason that physiographic provinces are unsuitable for human, statistical use, as in reporting the results of a census. There is little interest in the number of inhabitants of the Sierra Nevada-Cascade province, or in its production of wheat or apples. It could hardly show a significant product other than minerals and is unnecessarily complex for even a map of mineral products. But there is an enormous interest in the number of people in the Pacific coast valleys, and their production of grain and fruit. To report census data by physiographic provinces will serve no other purpose than to show how unsuitable these provinces are for the representation of human activities.

Geography is not to be regarded in its human aspects as the story of Earth and Man, but as the study of Man using and living on the Earth.

[5] *Annals Assoc. Amer. Geogr.*, Vol. VI, 1916, pp. 19-98.

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SRIHARIKOTA AND THE YANADIS

A SANDY ISLAND OFF THE EAST COAST OF INDIA AND ITS INHABITANTS

SUMNER W. CUSHING

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INTRODUCTION.—*Acknowledgments.*—In the way of introducing this paper I wish to acknowledge my indebtedness to Professor W. M. Davis and Harvard University for opportunity to visit the Orient and carry on the study outlined in this paper, and numerous other geographical studies.

The Organization of Responses to Geographical Environments.—To search out responses to geographical environments is often a task of great difficulty not only because environments are so complex but also because man responds differently to them at different stages of development. As the science of geography advances it may in time be possible to perfect an organization of its subject matter around three centers—land forms, climate, and stages of culture. It may be possible, for instance, to classify the influences which a young mountain mass located in the subtropical belt exerts upon a primitive people or upon a highly civilized people; or to classify the influence exerted by the same kind of mountains located in the subequatorial belt upon a primitive people. Investigations might in time reveal responses that primitive and advanced people give to every type of land form at various stages of dissection located within the different climatic belts.

This paper may be regarded as a first short step into such a scheme of systematic geography, since it deals with an island off a young coastal plain. The island is probably the simplest part of the simplest type of land form. Moreover, its inhabitants, simple jungle folk, are in the most elemental stage of evolution. The island has the monsoon type of climate.

THE SETTING AND PHYSICAL CONDITIONS OF SRĪHARIKOTA.—The Coromandel or the East Coast of India presents to the Bay of Bengal a

shoreline backed, except in a few places, with a monotonously low relief. If one braves the tumultuous shallow inshore waters of the bay from Calcutta to Cape Comorin his typical view is of a silver strand surmounted by jungle growth. Occasionally a light house, or a group of houses with a pier in front of them, takes the attention. Only once is the imagination stirred with the evidence of noticeable commercial activities and of the existence of an important center of population. That is while opposite Madras.

But the monotony of conditions suggested by the view from a boat is not borne out when one visits the people who inhabit the land that skirts the shore. Here one finds a broad fertile delta densely inhabited by a relatively progressive people who live by agriculture. There one comes to an infertile island that is occupied by a primitive jungle tribe. Again one follows for scores of miles a low sandy plain whose people take an intermediate rank in cultural development.

The variety of land forms found along the Coromandel is typical of the outer margin of a young coastal plain. Where large rivers pour their waters into the shallows of the bay broad deltas are built forward. Where the strong waves driven forward by the north east trades have agitated the sands of the bay bottom and piled them up above sea level there is likely to be a sand reef. Often these reefs are separated from the mainland by a lagoon or marsh. Most of the sand reefs along the east coast of India have been connected with the mainland by the filling with sediment of the lagoons that formerly backed them. The marshes thus formed are readily crossed except at the time of high river floods or unusually high tides. This paper treats of Srīharikota, the largest of the sandy reefs or islands that are still isolated from the mainland, and the Yānādis, the people who occupy it.

Srīharikota is located forty-five miles north of Madras and is separated from the mainland by a large lagoon called Pulicat Lake. The island stretches thirty-five miles from south to north and broadens to six miles toward the north. The soil is everywhere sandy and the relief is made up of sand plains, fixed dunes, blowout basins, and, on the lagoon margin, marshy plains. No part of the island rises more than a few yards above sea level.

Srīharikota is covered naturally with a dense jungle (as is suggested in Pl. VIIb). Evidently this growth means that the physiological dryness of the soil is counteracted by the high water table and the forty inches of rainfall which is brought chiefly by the northeast trades or the northeast monsoons as they are called in India. A variety of animal life inhabits the jungle. It ranges from wild pigs to jungle fowl and rats. Tigers rarely visit the island. Then they remain only a day or so, since there are no natural lairs.

These elements then, constitute the setting for the inhabitants (1) an island with its isolating influence, (2) a tropical jungle, (3) abun-

dant wild game, (4) a sandy soil. Let us see what response the people have given to each of these influences.

THE ISOLATION OF THE INSULAR POSITION.—*Cultural Development.*—The isolating influence of the island has been the supreme factor in the lives of the Yānādis. Srīharikota shares with a few mountain recesses in preserving some of the aborigines of India, "pre-Dravidians," as they are called. There is no record of the date of their arrival on the island. It has preserved them as a pure blooded tribe in all their primitiveness. Waves of conquest, waves of caste, waves of religion and of culture have swept over India and left these people untouched. For centuries currents of commerce on both sea and land have flowed past the island even within sight, but without effect on these people.

The Yānādis show the effects of their isolation in many primitive customs. (1) They have only attained a primitive hunting and fishing stage in their development. They have no weapon except a chance stick. They catch game by running it down. They dive and catch fish that burrow in the sand. (2) Their religion is that jungle of unhappy superstitions called "animism." They may be said to worship only on occasions such as weddings and funerals. (3) Their primitiveness is also emphasized by their habit of eating raw food or that merely scorched or heated. They make fire by friction as is shown in Pl. Va. (4) Although they are surrounded by water they have never made or used rafts or boats. It may be that the usual turbulence of the surrounding waters is in part responsible. (5) Their bodies and clothes are never washed. In Pl. VIIa the gray of their dirty clothing is shown in contrast to the white of the interpreter's turban. The government has introduced among them the "dhobey," the Indian washerman, with the hope that they might get the habit. (6) Conjugal relations also indicate a primitive people as has been pointed out by Thurston.[1] The Yānādi marriage is, as one would expect, a somewhat free and easy affair. In contrast to Hindu practise it is generally arranged by the inclination of the contracting parties, and is readily dissolved at the caprice of either. The marriage ceremony is no indispensable necessity. Usually girls marry as soon as they reach puberty, as is suggested by Pl. IIIa. Pregnancy before marriage is no crime. Polygamy is common.

THE RESPONSE TO THE JUNGLE.—*The Plant Products.*—The low stage of culture of the Yānādis has one contrasting feature. They have a wide and practical knowledge of their jungle. Every kind of tree, herb and vine has a name. The properties of each are as well known to them as the letters of our alphabet to us. They gather roots, fruits, leaves and honey for their food and know well the best season for

[1] Castes and Tribes of Southern India, Madras, 1909, VII, 423 et seq.

each variety and where it grows best. They have learned by experience the properties and uses of herbs and roots in medicine. Every ache and pain has its supposed remedy in the jungle flora. Fortunately there is no tree in the jungle that readily yields juices that can be fermented into intoxicating drinks. Therefore the Yānādis are by necessity a temperate people.

This expert knowledge of the jungle led the government in 1835, when it took possession of the island, to employ the Yānādis in collecting minor forest products. In return for their labor the government at first paid them in clothing, grain and money in order that their position might be improved. The employment has continued to the present. They collect chiefly *nux vomica*, soap nuts, tamarind, rattans, sarsaparilla roots, barks that are still used in South India as dye-stuffs, and various leaves, roots, and bark that are marketed in India or elsewhere for medicinal purposes. A forest officer representing the government pays them according to the quantity they bring in. Each person earns about four cents per day. This information and other interesting items were given the writer of this paper by C. Ballayya Nayudu, the forest officer in charge at Srīharikota. He has recently set forth the forest conditions on the island in a brief paper.[2] A group of collectors of minor forest products is shown in Pl. X.

After the government had induced the Yānādis to collect minor forest products it introduced coolies from the mainland to cut firewood to be sent to Madras City, and to teach the Yānādis the art. But they worked under protest. They preferred to be let alone to enjoy the wild life of the jungle. Gradually however they got accustomed to it and now do better work than the immigrant coolies. A group of workers is shown in Pl. VIIb. In this forest work they now earn about four cents per day. With the few cents earned in forest work they buy trinkets (Pl. IV), an occasional pot for cooking purposes or a basket for collecting their jungle foods, and rarely a bit of cloth for clothing. A little money goes to the Yānādi "priest" for exemption from being annoyed by some jungle devil or ghost.

The Running Ability of the Jungle People.—The game of the jungle is an important source of food. From ten to twenty people may combine to follow the footprints of animals or birds. After they are traced out, the animal is chased until tired out and then killed. The flat sandy island offers no effective hiding place for animals. In the case of birds it is necessary for one man to climb a tall tree in order to direct the others as the bird is put to flight by beaters and seeks safety in another place. After many flights the jungle cock, for instance, is tired out, caught and killed. But it has taken many people an hour or so to hunt one creature. This method of hunting and the

[2] "Indian Forester," Sept. 1910, 515-521.

plain on which they live have developed the Yānādis into good runners. Hence the government employs them in running with the freight cars on the narrow gauge track that is used to collect firewood from several parts of the island. The work is shown in Pl. VIIIb. The fleet foot is also an asset to those who have migrated to the mainland. There they are occasionally hired to replace ponies in hauling passenger vehicles, the so-called "pony jutkas." When hauled by these men they are called "Yānādi jutkas." Such a vehicle is shown in Pl. XII. The Yānādi jutka is far more comfortable than the pony jutka, so skilful are the pullers and pushers.

THE RESPONSE TO THE SANDY SOIL.—Probably the most unique and interesting response that the Yānādis yield to their simple environment is in reference to the sandy soil. Since the Yānādis have no floors to their huts, as is suggested in Pls. IIIa-Va, and no mats, beds nor chairs, and since they wear neither shoes nor stockings, it may be said that they are intimately in contact with sand all of the time. It is literally true that they are born on sand, sleep on it, live on it, die on it and are buried in it.

Susperstitions and Customs.—It is expectable, therefore, to find that the sand plays a part in many of their superstitions and customs. Here are two samples. As a punishment for adultery, the unfaithful woman is made to stand out in the hot sun on the hot sands for a whole day with her legs tied together and with a basketful of sand on her head. The Yānādi in the forest sharpens the cleaver the government has loaned him to trim trees by whetting it on a flat piece of wood sprinkled with sand grains, as in Pl. VIIb.

Footprints and Honesty.—The remarkable ability to track animals the Yānādis possess is a response to the sandy soil. The sandy soil faithfully preserves footprints much better than our dry seashore sands. The Yānādis are able to identify the footprints of individual people as well as of different kinds of animals. A person is known from the footprint he makes. The writer had the opportunity again and again of testing this ability of interpreting tracks. It would seem that the Yānādis tell human footprints as readily as we tell faces. The headman of one village I visited was able to name the footprint of not only every man, woman and child in his village, but that of everybody in the nearby villages as well. Some of the Yānādis are able to identify a footprint after they have associated it with the owner only once. Of course it must be remembered that few people visit the island because of its isolation. It must further be recalled that it is the bare foot that makes the print and feet have as much individuality as hands.

There is evidently a relation of cause and effect between the sandy

soil that preserves foot prints and the remarkable honesty of the Yānādis. The forest range officer of the island and the judge that occasionally visits the island to hold court, both Hindus, agree that the Yānādis are noted for their honesty. It would seem that the sand may be responsible for this one feature of high ethical standards. No person steals since his footprints so identify him that he could easily be traced and found. When the government first induced the Yānādis to work in the forest some seriously objected and ran away from their own village. But they were speedily tracked by the headman and brought back. Even where they had crossed ponds in blowout basins the headman had no difficulty, as he walked around the margin till the tracks reappeared. This illustrates the ease with which thieves might be run down.

This relation between the sandy soil and honesty is brought into conspicuous relief when one studies those members of this same Yānādi tribe that have migrated to the mainland where the soil is laterite. There, where the soil does not retain footprints, they are notorious thieves and robbers. In this respect they are worse than any other people, as is pointed out in the "Gazetteer of the Godavari District."[3] On the mainland they retain the tool which on the island they used for digging roots for food, but here it is used as a jimmy for digging through the mud walls of houses in order that they may enter and steal. Following the principle that "it takes a thief to catch a thief," many of the people of the mainland now employ Yānādis as night watchmen. A group of such men is shown in Pls. XIIIa and XIIIb. A watchman will travel about the group of houses in his charge with such jungle spryness that there is little likelihood for an attempt at burglary and even less of success. But the food he receives daily from the protected people and the few cents at the end of each month are more in the nature of blackmail than an honest wage.

A similar relation between soil and ethics has been brought out in a recent article by Professor W. M. Davis.[4] The case is originally cited by Brunhes.[5] He points out that the sands of the oases of Souf, in northern Sahara, so carefully preserve the footprints of man and animal that the people have become expert in identifying them. They are even able to recognize the tracks of their own camels as different from those of their neighbor's camels. Here, too, honesty is a marked characteristic of these expert trackers in their isolated environment. Brunhes claims the sandy soil has developed honesty. He makes the case stronger by pointing out the comparative dishonesty of the dwellers in the more stony parts of the Sahara. Hence it seems

[3] F. R. Hemingway, Madras, 1907, 192-193.

[4] "Human Response to Geographical Environment," The Bulletin of the Philadelphia Geographical Society, XI, No. 2, Apr. 1913, 1-40.

[5] "La Geographie humaine," Paris, 1910, 515-539.

that the two cases are remarkably parallel. Each surely supports the other.

To return to Srīharikota we must conclude that there the sand spells honesty. There the Yānādis had established a wonderful Bertillon system centuries before Bertillon was born. Records of identification of every inhabitant of the island have been constantly kept in the minds of the people. In Srīharikota even he who runs must give his identification mark. The sand can tell no lie. The sand breeds honesty.

Conclusion.—Such are the influences that are exerted by the simplest part of a simple land form upon a primitive people. It is interesting to contemplate how such an environment would influence the life of an advanced people. How does such an island off the Atlantic coastal plain in North or South Carolina, for instance, affect the life of its inhabitants? This takes us into a different climatic belt; hence the influences of two new factors would have to be untangled. Such a study would be the logical second step into one kind of systematic geography. Present geographical investigations seem to be carried on in a sort of sampling manner. One student of the science samples one field of geography, another selects another corner of the subject to investigate, and so on, all in a seemingly haphazard way. General progress would surely be better fostered if a definite system were to be adopted by a leading geographical society like the Association of American Geographers and if serious students of the science were encouraged to follow out its plan.

ANNALS OF THE ASSOCIATION OF AMERICAN GEOGRAPHERS
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THE EROSIONAL AND DEGRADATIONAL PROCESSES OF DESERTS, WITH ESPECIAL REFERENCE TO THE ORIGIN OF DESERT DEPRESSIONS

WILLIAM HERBERT HOBBS

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FOREWORD.—*The Psychology of Theory Making in Science.*—The writer has long interested himself in the psychology of the making of scientific theories, and has given some attention to the manner in which the great events of a period, the accepted fashions of intellectual processes in vogue at the time, and the personalities of the dominating scientific authorities, have reacted and interacted to produce what we

sometimes refer to as standard doctrines—the accepted theories. In the field of seismology it is not difficult to show how the so-called centrum theory of earthquakes, which held the center of the stage for half a century (1857-1907) and determined the trend of investigation, is directly traceable to the Crimean War, since it was there that the reputation of Robert Mallet was made in the field of ballistics. On the basis of his researches upon the life of great guns, Mallet was able to obtain the financial support of the Royal Society for a study of the Neapolitan earthquake of 1857, and in his report upon it to carry over successfully to the disturbances within the earth's outer shell, ideas gained from explosions and the propagation of their shocks as harmonic motions through homogeneous media.

The study of glaciers has similarly been given its trend as a consequence of the accident that pre-existing glaciers of continental dimensions were visualized from Alpine glaciers before existing glaciers of continental type had been examined. A great personality and the greatest authority upon the diminutive mountain glaciers of the Alps, was the first to visualize the great glaciers of "The Ice Age," and quite without warrant to carry over to them those attributes which he had found to belong to the small ice streams of the Alps.

It is only natural that the prepossessions of geologists concerning the geological processes of desert regions, should have been largely carried over from the humid regions of temperate zones, with which they had long been familiar and within which geological science had grown up. In America particularly this seems to have been true, notwithstanding the fact that important areas of desert were early studied and described in monographs which have greatly enriched the field of knowledge.

Much impressed by that great work of Johannes Walther, "The Law of the Desert," the writer had felt a longing to visit the deserts of northeastern Africa, to which Walther has devoted so much attention and where complete aridity is perhaps more nearly realized than elsewhere upon our planet. The desired opportunity came in the winter of 1912-13, and the studies then made constitute the basis of the present work.

Acknowledgments.—The author is under special obligations to the Survey Department, Egypt, for copies of valuable maps; to Mr. G. W. Grabham, M. A., Geologist to the Sudan Government, for many courtesies and for acting as his guide in excursions made from Khartum as a center; to Mr. Wright, who at Markaz el Sherikah was in charge of the office of the Corporation of Western Egypt and who gave him valuable assistance in an excursion made in the Oasis of Kharga.

In the later study of the desert stones, the author is under obligation particularly to Professor Edward D. Campbell, Director of the Chem-

ical Laboratory of the University of Michigan, and to William C. Dowd, his Assistant, for a chemical study of the desert rinds. To Dr. A. L. Parsons, Professor of Mineralogy at the University of Toronto, the author is indebted for a study of the hardness of these specimens.

THE CONTRASTED FEATURES OF HUMID AND ARID LANDS.—*The Intricate Patterns of the Erosion Surfaces in Humid Regions.*—Within humid temperate regions, those with which we are best acquainted, the erosion surface of the land is very largely the handiwork of running water, or that of glacial ice subsequently laid under the action of running water. Wherever water has been the sole agent of degradation, the design imprinted upon the land surface is an arborescent tracery cut into the surface—an intaglio—which starting from stem-like grooves at the ocean margin divides and subdivides the area with ever greater complexity as it recedes from it. Most deeply graven at the ocean border, the incisions become both shallower and finer with each succeeding ramification. Though the incisions be cut so deep as to remove all the original surface and so yield a complex of ridges, the pattern is none the less truly preserved as an intaglio.

Glacial ice insofar as it is in small masses and restricted in its action to the trenches of the pattern produced by the action of water, though it modifies the form of the gravings and particularly where they are less deeply incised, does not in any large degree efface the general pattern due to the running water. Quite otherwise is it where ice masses of continental dimensions instead of being restricted to the existing valleys spread broadly over the entire country. By a combination of sculpturing and moulding processes the inherited intaglio is gradually transformed into a cameo, and the pattern which before was arborescent is now hidden beneath a series of raised arcs ranged in sweeping festoon series. So soon as the ice has disappeared, the land surface is usually once more laid under the action of running water, and upon the cameo design there is faintly imprinted an intaglio tracery of arborescent character, but one far less symmetrical and orderly than that which under other conditions is yielded by running water. Sometimes the original deep intaglio is not entirely effaced when the glacial cameo has been raised above it, and the resulting surface is so much the more intricate from its shaping in three successive stages, each with a different pattern. Yet whatever may have been the respective rôles of water and ice in the shaping of a land surface, the intricate tracery of the intaglio which results from river erosion is never entirely absent, affording as it does the most striking contrast between the surface of the lands best known to us and that of the neighboring portions of the ocean floor.

The Simple Models of the Erosion Surface in Arid Lands.—The orderly tracery which is etched into the land surface within temperate humid regions is, however, in sharpest contrast with that of the arid lands. As we have seen, the intaglio pattern is to be ascribed to the selective action of the eroding agent operating under control of definite laws. It is the general absence from the arid lands of an eroding agent of selective character, which accounts for the absence of any similar patterned surface in such regions, and its restriction in semi-arid lands to a narrow marginal hem about the greater depressions. In the true deserts the degrading agents attack the entire exposed surface of the land with nearly uniform vigor, modified only as the materials attacked offer varying degrees of resistance. The main agent is the sun's heat, manifested upon the one hand in large and sudden changes of rock temperature, and upon the other in prevalent strong winds which lift and transport all the finer rock fragments. To these is added at infrequent intervals and locally, heavy downpour and flood-water here likewise largely non-selective in its action, since it travels in the main as sheet-flood either of water or mud.

As regards the larger relief features in desert lands, they are for the most part broad and notably flat areas which pass from one level to another, not as a rule in curving slopes as is so common in humid regions, but through a series of abrupt steps or terraces joined to each other by the even inclines of talus. We miss also, that lack of balance in the accomplished excavation which is so characteristic a feature of the land sculpture in humid regions. Within the arid lands the removal of rock materials has yielded vast flat-bottomed depressions within the surface which are shut in by steep walls and have been variously described as Djufs,[1] *Wannen* (pans),[2] bolsons,[3] and intermont plains.[4]

Desert Weathering Contrasted with that of Humid Regions.—In order properly to understand the erosional and degradational processes of deserts, one must first divorce his mind from the preconceived notion that weathering processes are the same in arid countries that they are in the more familiar humid temperate regions. Of the two broad classes of weathering processes, chemical and mechanical, the former generally described under the term decomposition, are largely dependent upon the presence of nature's common solvent medium, percolating water. That chemical reaction may occur, an intimacy of

[1] Karl A. v. Zittel, Beitraege zur Geologie und Palaeontologie der libyschen Wüste, etc., Palaeontographica, vol. 30, 1883, pt. 1, pt. 9-10.

[2] Albrecht Penck, Morphologie der Erdoberfläche, vol. 2, 1894, pp. 235-251.

[3] R. T. Hill, Topographic Atlas of the United States, folio 3, 1900, p. 8. Redefined by C. R. Keyes, Am. Jour. Sci., vol. 165, 1903, pp. 207-210.

[4] C. R. Keyes, Rock-floor of the Intermont Plains of the Arid Regions, Bull. Geol. Soc. Am., vol. 19, 1908, pp. 63-92.

contact of the reacting substances is required which demands a fineness of subdivision such as is reached only in fusion or solution. Fusion being here out of the question, decompositional processes are in weathering almost entirely restricted to those districts where rainfall is abundant; their place in arid lands being taken by the mechanical processes of disintegration and by certain reactions apparently in part at least of a chemical nature which are restricted to the outermost skin of the rock and yield the well-known protective rinds.

The disintegrating processes of exfoliation (often controlled by joints to produce segmented columns), crumbling disintegration, diffission (Walther's term, *Insolation*) and case-hardening, are well described in German by Johannes Walther,[5] and the reader unfamiliar with that language may perhaps be referred to the author's Earth Features and their Meaning.[6]

CASE-HARDENING OF ROCK.—*Chemical and Mineralogical Study of Protective Desert Rinds.*—At various localities, but particularly in the area northwest of the Pyramids of Giza, about Luxor, in the Great Oasis, and near Khartum, many specimens of loose desert stone were collected from the surface armor of pebbles upon the desert floor, specimens having rinds which represent various differences in appearance, in thickness, and obviously in the chemical changes which have taken place in them (See Plates XIV and XV). The rinds of two of these specimens have been subjected to special study with reference to changes in hardness and in chemical composition which they have undergone. The chemical study has been conducted by Professor Edward D. Campbell, Director of the Chemical Laboratory of the University of Michigan, the analyses being made by his assistant, Mr. William C. Dowd, B. S. The same specimens have been examined with regard to hardness by Professor A. L. Parsons, of the University of Toronto with use of the special form of schlerometer which he has devised.[7]

A "Soft" Rind.—One of the specimens studied is a brownish yellow variety of dolomite with a rind which has an average thickness of a centimeter or more which appears upon the specimen as a cornice-like marginal extension where undercut by the action of the driven sand (Plate XIVa). When broken through the specimen shows the rind to be somewhat more strongly colored by the iron stain characteristic of the entire specimen.

The analyses of core and rind made upon this specimen by Mr.

[5] Das Gesetz der Wüstenbildung, 1912.

[6] Chapters on Weathering and on Deserts.

[7] A. L. Parsons, A New Schlerometer, *Am. Jour. Sci.*, vol. 29, 1910, pp. 162-168.

Dowd, revealed the interesting fact that though the rock as a whole is a dolomitic limestone with a ratio of dolomite to calcite molecules of about 6:1, the thick rind is by contrast a nearly pure calcite.

ANALYSES OF DESERT STONE AND ITS RIND FROM SPECIMEN COLLECTED IN THE LIBYAN DESERT TO THE NORTHWESTWARD OF THE GREAT PYRAMIDS, BY WILLIAM C. DOWD, B. S., ASSISTANT IN CHEMISTRY, UNIVERSITY OF MICHIGAN

	Interior of Stone	Theoretical Comp. of Dolomite ($CaCO_3$, $MgCO_3$)	Rind	Theoretical Comp. of Calcite ($CaCO_3$)
SiO_2	0.19	—	0.51	—
Al_2O_3	0.05	—	0.26	—
Fe_2O_3	0.34	—	0.38	—
MnO	0.04	—	0.03	—
CaO	33.74	30.4	54.92	56.0
MgO	18.34	21.7	.28	—
Loss on Ign.	47.29	47.8	43.64	44.0
	99.99	100.0	100.02	100.0

It is at first rather surprising to learn from these analyses that the rind, which has offered more resistance to the bombardment by the grains of driven sand, is very much softer than is the normal rock. Confirmation of this is furnished by the determinations of hardness made by Professor Parsons after artificial surfaces had been prepared and carefully polished by a lapidary. Some difficulty was encountered in securing smooth surfaces owing to the presence of small pittings, in consequence of which the tests for hardness gave results which varied between rather wide limits. The average of twenty-seven readings made upon the dolomite interior corresponded to a pressure of 5.1 grams, whereas the average of thirty-two readings made upon the calcite rind of the specimen corresponded to a pressure of 2.52 grams. The rind would appear therefore to be only about one-half as resistant to abrasion of this type as is the interior. None the less the specimen indicates with sufficient clearness that resistance to the bombarding action of sand grains is notably greater for the rind of soft calcite than it is for the core of harder dolomite. Professor Parsons has drawn my attention to the fact that the wear upon rubber tubing used in sand pumps is greater the harder the rubber, and that paper is so resistant to a sand-blast that it is used as a guard when letters are cut upon glass by this process.

The elimination of the magnesium carbonate from dolomite in the rind producing process, is obviously of considerable interest. Professor Campbell has offered the following suggestion:

"Magnesium carbonate is much more readily dissociated than is calcium carbonate, so that one might expect that it would be removed

more readily than the latter under the desert conditions to which these limestones have been subjected."

The carbon dioxide which results from the dissociation of the magnesite molecule, would be lost in the atmosphere, and it is not improbable that the finely divided magnesium oxide would be sucked out of the rind and carried away during high winds.[8] That this process of elimination of magnesium carbonate has been accompanied by a recrystallization of the calcite residue, is abundantly proven by examination of a microscopic thin section which includes both core and rind, for the calcite of the rind is in coarser grains than is the dolomite of the core.

A Black Rind.—The other desert rind which was especially examined, is found upon a specimen of a grey variety of Mokattam Limestone from the same district, which in the unaltered interior reveals in the microscopic section the silicious infusoria which are characteristic of certain layers of this formation. The rind of this specimen is in three distinct layers, the outermost lustrous black and a millimeter in thickness, immediately beneath which is a red layer of oxide of iron of the same thickness approximately. The main portion of the rind has a thickness of several millimeters on the average and is made apparent upon the fractured surface of the specimen by its color, which is somewhat lighter than the unaltered rock.

The material for analysis of the rind was obtained by grinding away the core material from a fragment of rind and core. It represents, therefore, the rind with, probably, some small portion of core attached.

ANALYSES OF DOLOMITIC LIMESTONE AND ITS DESERT RIND, FRAGMENT FOUND IN THE LIBYAN DESERT NORTHWEST OF THE GREAT PYRAMIDS OF GIZEH.
ANALYSES BY WM. B. DOWD, B. S.

	Interior	Rind
SiO_2	7.04	50.99
Al_2O_3	.49	1.33
Fe_2O_3	.08	.22
MnO	Trace	.14
CaO	43.96	21.96
MgO	6.47	3.79
Loss on Ign.	42.07	21.33
	100.10	99.76

These analyses by Mr. Dowd show the unaltered material of the interior of the specimen to be a dolomitic limestone in which the magnesite molecule is admixed with the calcite molecule in about the proportion of 1:3, the imbedded silicious infusoria giving a silica content of seven per cent of the whole. The impure rind is shown

[8] Cf. Sickenberger, Zeitsch. d. d. geol. Gesell., 1889, p. 314.

to be about one-half silica and one-half dolomitic limestone of approximately the same composition as that of the interior.

A section of this rind with the attached portions of the core was digested for two weeks in a mixed solution of five per cent nitric acid and ten per cent hydrochloric acid, the residue being taken from the menstrum at intervals for scraping and washing. At the end of the period there remained a residual shell of a dirty white color corresponding in thickness to the sub-surface rind in the original specimen, and with a somewhat brownish outer surface. Only 2.43 per cent of this shell remained as an insoluble residue after one hour's digestion in a five per cent solution of nearly boiling hot sodium hydroxide. This ready solution in caustic soda indicates that the silica is opaline, and examination of the thin section confirms this view. In the section the silica is revealed in the interior portion in the form largely of organic rests as chalcedony. These infusoria can be observed to extend into the rind without noticeable change of character, whereas the remaining portion of the rind shows the dolomite of the core to be in large part replaced by opaline silica, which affords a birefringence of the rich blues and yellows to contrast with the calcite colors of the higher orders. In addition the rind is considerably stained with ferrite and is on this account easily differentiated from the core when examined in ordinary light.

The development of opal within the rind confirms observations made in other desert regions, so that opal has come to have the value almost of a fossil in indicating arid climatic conditions, a distinguishing characteristic which it shares with gypsum. In view of the extreme aridity of the region where the specimens were found, the writer inclines to the view that the moisture enters in the process of the change not as rain but much more probably as dew.

The studies by Professor Parsons of the hardness of this specimen, indicate for the interior portion as the result of four tests which are in very close agreement, a hardness corresponding to 2.8 grams of pressure, about the hardness of calcite. Three almost equally consistent tests made upon the inner rind gave a hardness corresponding to 1.73 grams of pressure, or something more than half that of the unmodified interior rock. The thin red layer between the innermost rind and the outermost black varnish was almost too thin for testing, but a single scratch gave the result 1.6 as against the average 1.73 of the main inner rind, which indicates with much probability that it is mainly of the same material though strongly colored with hematite. These results are somewhat puzzling in view of the larger percentage of silica in the rind as compared to the core, and they perhaps indicate the difficulty in applying tests of hardness to aggregates of such different bodies as silica and carbonates.

SAND-BLAST EROSION.—*Observed Range of More Effective Action.*—Oddly enough little attention seems to have been directed to sand-blast erosion by geologists, most general texts laying stress only upon the differential erosion effects indicated by the well-known "stone lattice" which is developed wherever notable differences of rock hardness correspond to a more or less definite pattern. Moreover, the mushroom rocks (*Pilzfelsen*) so common in deserts, seem generally to have been explained by the assumed existence of a stratum of less resistant rock near the level of the general surface, which layer has in consequence first fallen a prey to weathering processes. While without doubt in many instances, such, for example, as those figured by Walther,[9] the weathering of a less resistant layer near the ground level may be sufficient explanation for the canopy-like overhang, it is believed that in many other instances the mushroom forms are to be accounted for solely by sand-blast erosion strictly limited in vertical range and close to the level of the ground.

The writer was first strongly impressed by the narrow range in effective action of the natural sand-blast from observations made in the Great Oasis of the Libyan desert, where the cast-iron telegraph poles lining the railway were well burnished by the flying sand to a height above the ground of only about a yard. Here also the thick adobe walls of the ancient Roman fort near Jebel Um el Ghenneiem known to the natives as "El Deir," are deeply undercut by the same process with the upper limit of effective abrasion essentially the same as noted on the telegraph poles, except where accumulations of sand have locally raised the surface of the ground (Pl. XVI).

To the north of Khartum and east of the Shabluka gorge of the Nile, the granite knobs which as "island hills" rise out of the great plain, have been beautifully burnished by the sand-blast to the height of about a yard, at which elevation the polished zone meets the remaining upper portion of the granite surface in a fairly sharp boundary. Even from a considerable distance the lower polished zone is plainly outlined against the dark brown surface above (Pl. XVIIIb).

Sphenoidal Elongated Ridges Fashioned by the Sand-Blast.—Wherever the winds maintain a constancy of direction throughout the year, ridges of peculiar form result from sand-blast erosion. Throughout a large area of the Libyan desert the direction of winds throughout the year varies through a small arc only to the westward of the meridian, and hence such ridges as are carved by the sand erosion take on definite forms. Where the rocks are of little strength, these ridges are carved with comparative ease, and the limited vertical range of the action causes undercutting wherever projecting masses of rock

[9] Johannes Walther, Das Gesetz der Wüstenbildung, 2te Aufl., 1912, figs. 101-105.

exceed in height the yard or thereabouts to which effective abrasion extends. Particularly fine examples are supplied by the eroded lacustrine beds exposed near Markez el Sherikah in the great oasis. These weak clayey beds are intersected by a rectangular system of vertical joints, and in consequence the windward surface, as it has been undercut by the sand-blast, has been fashioned on these planes and left as a nearly vertical cliff sometimes notched at the base as is a sea cliff. That portion of the sand which is swept around and over the projection scours it upon the sides and lee surface and shapes it eventually in general conformity to the lines of stream flow (Pls. XIX and XX). The form assumed under the action of the sand-blast is an elongated sphenoid strikingly unsymmetrical, with longer axis directed with the wind and having the steep and small face to windward. Where groups of these features appear upon the floor of the desert, they strikingly suggest a school of porpoises emerging at the same instant for their leaps out of the water (Pl. XIX). Low secondary features which have been sculptured by sand-blast in the deserts of Central Asia are described by Sven Hedin under the term *jardangs,* and here also as the winds blow with much regularity from one quarter they possess a very definite and constant topographic form.[10]

Upon the broad hamada which separates the Great Oasis in the Libyan desert from the rift of the Nile, the "glass hard" limestone which forms its upper capping layer, has in local areas and under constant northerly winds been fashioned into unsymmetrical ridges by the flying sand, but since the sculpturing process goes forward here much less rapidly than in the case of the weak lake beds of the oasis, the original surface has been much less profoundly altered and the ridges present less uniformity in contour. It is worthy of note, however, that the lower layers for a few feet above the general level of the hamada consist of the strongest rock, whereas above this layer there occurs a relatively soft bed with numerous hard flinty concretions. These latter through undermining by the sand-blast have in some areas been liberated from their matrix in large numbers and lie scattered thick over the surface, thus resembling a field of watermelons, and they are in fact so called (*el botiq*) by the Bedouins.

Where the surface features are fashioned from the hard lower layer, the projections which result often lie close together so that the sand-laden wind has passed between them as through bellows pipes. If these obstructions do not exceed a yard in height, the windward or stoss ends are found beautifully polished to the top, but if much higher a rough unshaped upper surface may often be seen.

[10] Sven Hedin, Scientific Results of a Journey in Central Asia, 1899-1902, vol. 2, 1905, pp. 238-242, pls. 24-27.

Rate of Undercutting by Sand-Blast.—During the windy days of early summer, erosion by flying sand within the area of the Great Oasis is excessively rapid. Ball tells us that a piece of tin plate put out to the blast for two days had all the coating removed, and that glass bottles in the same time were made quite dull by the scratching action of the driven sand.[11] On the protected surfaces of rock in the same region, on the other hand, erosive action has been so slight that after 1,400 years inscriptions drawn in red ochre are entirely legible. A quite remarkable pair of examples of rapid sand erosion on projecting buttes has been furnished by Obrutchev.[12]

A good measure of the rate of sand erosion on well-made adobe was furnished by the corner posts of a cemetery lot at Markaz-el-Sherikah that had been erected about a year before the writer's visit. Owing to the constancy of the wind direction, these posts had been undercut about the northwardly directed angle only, and there to a depth near the ground of five to six inches. The eroded portion extended up from the ground about two and a half feet, and wherever small pebbles had been included in the mud of the adobe these had locally protected the material behind it and so yielded small hoodoo-like headed pillars directed toward the wind and some three inches in length (Pl. XVIII).

Such slender "demoiselles" resulting from the imbedding of harder nodules within rocks whose surface has been drilled away by natural sand blast, have been described by Walther. Especially beautiful examples of such structures were collected by the writer from the notch near the summit of Dj. Um. el Ghenneiem near the eastern wall of the great Oasis. The rock is the compact Eocene limestone and the capping nodules the numerous imbedded shells of *Operculina Libyca* (Pl. XXI). The spines are sometimes fully an inch in length, and apparently as a result of local wind currents beneath the zigzagging escarpment of the eastern wall of the depression the spines project in nearly opposite directions from certain angles of the rock surface (Pl. XXIb). An example of a relief pattern supplied by the hard phenocrysts of a rhyolite is reproduced in Plate XXIIb.

Possible Explanation of the Limited Vertical Range of Effective Sand-Blast Erosion.—When it is borne in mind that within desert areas particles of sand are during sand storms raised to very considerable heights, one is at first surprised to find that the efficiency of sand-blast erosion should here be both so limited and so definite in range. For this there are probably two principal causes. It is certainly true that the size of the lifted grains of sand falls off

[11] John Ball, Kharga Oasis, Its Topography and Geology, *Geol. Sur. Dept.*, 1889, part 2, Cairo, 1900, p. 92.

[12] Eolovyi Gorad (Russian), 1911, figs. 13 and 14.

rapidly as elevation above the ground increases beyond a few feet, and that only the larger grains are competent to bombard obstructing surfaces with much force. For the smaller grains adhesion and friction with the air is relative to their mass, so large that they acquire but little momentum, whereas for the larger particles the momentum (which measures the striking force) is for each particle more nearly equal to its mass into the square of the wind velocity. But erosion by sand-blast depends upon the number of hits as well as upon the striking force of each sand grain, and it is the lower zone of the air in which the density of the sand-air complex is particularly large. Within this zone during a strong wind the air highly charged with sand may be looked at in a somewhat different way and regarded as a fluid whose density is two or three times that of the air alone (.0048 to .0072).[13]

Added to the chipping effect of the sand bombardment upon an exposed rock surface, there is the scouring effect of the grains which strike glancing blows.[14] Now the chipping and scouring actions both depend upon the greatly increased velocities within the eddies which exist in the lower layers of the air, and it is highly probable that the upward limitation of eddies having sufficient strength to lift the larger sand grains has fixed the sharp upper limit of more effective sand-blast erosion. To realize how great may be the velocity difference between the eddies and the surrounding air, one has only to consider the contrast between the larger local eddies and the surrounding air at the time of destructive storms.

Air and water are fluids which are controlled in their movements by similar laws, and the problems of transportation of debris by these fluids differ chiefly in the different specific factors of viscosity. For water flow as modified by friction on solid surfaces, a valuable experimental study of the formation of eddies was made by Reynolds in 1883.[15] It was found that the less viscous the fluid the more prone it is to eddy, that eddying is excited by any roughness of the surface over which the current flows, and by any lack of steadiness of the current itself. It was further shown that there is a critical velocity of the current above which eddying takes the place of a direct forward flow.

Much knowledge of the nature and the dimensions of the air eddies near the surface of the ground has been supplied by Cornish in a

[13] Herbert Chatley, The Force of the Wind, London, 1909, pp. 77-78.

[14] Chatley has given a rough formula for the scouring action, namely AV^2 (.00001 to .000015), where A is the area wetted (in water) in square feet and V is the velocity of the wind in feet per second (l, c. p. 79).

[15] Osborne Reynolds, An experimental investigation of the circumstances which determine whether the motion of water shall be direct or sinuous and of the law of resistance in parallel channels, *Phil. Trans.*, 1883, pt. II, pp. 935-982.

study, in part experimental and in part observational, the latter carried out in the Egyptian Desert.[16]

Cornish's experiments show that over a flat sand surface the effect of a strong current of air is to produce ripples of sand corresponding in position in the plan with the eddies which are found in the lower stratum of air, and that the wave length and amplitude of the ripples increase steadily with the time which the wind blows over the surface. The ripples run transversely to the wind direction and are frequently striated along the wind direction. The air motions within the eddies thus appear to resemble the motions of ranks of hoops traveling forward with approximately the same velocity. When the force of the

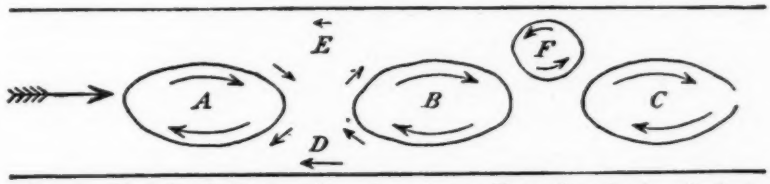


FIG. 1. Ideal longitudinal section of a stream, illustrating the hypothesis to account for the sub-surface position of the level of maximum velocity (after Gilbert).

wind falls off the ripples fill and becoming less distinct, the fall of a shower of sand soon smoothes out the surface. But this is again quickly covered with ripples under the renewed action of a strong current of air. A limit seems to be set to the size of the ripples, for any increase in height of the windward ridges though increasing the strength of the eddy directly above and causing a forward saltation of the grains, reduces the height of the ridge at the same time that it contributes toward the filling of the trough in front. A lateral transverse differentiation in the force of the eddies, which is rhythmic as regards space, produces undulations within the ripples and in some cases the horseshoe-like depressions in the sand which have become known as *fuljes*.

Though Cornish appears to find that heterogeneity of the sand is necessary for the formation of ripples—the larger grains producing small eddies which are sufficiently powerful to lift the smaller grains in the vicinity—the work of other observers indicates that eddies are

[16] Vaughan Cornish, On the formation of sand dunes, *Geogr. Jour.*, Vol. 9, 1897, pp. 278-309. See also with reference to water ripples H. Blasius, Ueber die Abhängigkeit der Formen der Riffeln und Geschiebebänke vom Gefälle, *Zeitsch. f. Bauwesen*, Vol. 60, 1910, pp. 466-471, Atlas, pls. 49-50. The mathematical side of the subject has been developed with literature references by A. E. H. Love, Hydrodynamik, Encyklopaedie der Math.-Wissensch., Vol. 4, Mechanik, (vol. 1), pp. 76-83 et seq., and for air especially by S. Finsterwalder, ibid, Aerodynamik, pp. 149-170.

produced in the air even over a smooth surface. Gilbert explains this as due to the couple caused by friction upon the floor or ground, which retards the forward movement of the air; and he makes this fact and the existence of secondary reversed vortices immediately above account for the sub-surface position of the level of maximum velocity of current.[17] (See fig. 1).

We are inclined to believe that in this distribution of the eddies is to be found the best explanation for the sharp upper limit of effective sand-blast action, the limit falling at the upper level of the primary "forward" eddies, at which level they are replaced by the secondary "backward" eddies. (Fig. 1.)

To no one are we more indebted than to Professor Brunhes for emphasizing the importance of the eddy in erosional processes both sub-aqueous and sub-aerial.[18]

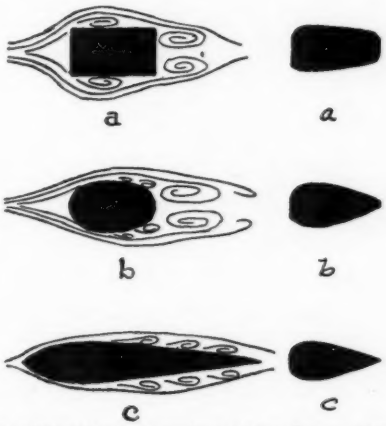
Side-lights upon the Position of Eddies in Fluids Supplied by the Field of Ship Construction.—Experimentally the study of eddies within air currents above the desert may be approached from an entirely different angle. The general similarity of the mechanical conditions within the two types of fluids has already been made use of and conclusions drawn. In a wholly different field, that of ship construction, experiments have been conducted by Ahlborn which are most illuminating.[19] As regards the formation of eddies within the fluid it is obviously immaterial whether the fluid is in motion and the obstruction stationary, as in the desert problem; or the fluid be stationary and the obstructing solid body drawn through it. In Ahlborn's experiments bodies of various shapes were drawn at uniform rates through water within a tank. and by means of special illumination of particles of lycopodium powder which was disseminated in the water, the effects were photographed by a moving camera. By attaching coarse grains to the surface of a board, eddies of sufficient amplitude were produced to show plainly in the photograph (Pl. XXIIIa). A board placed at right angles to the direction of translation and drawn through the water, reveals in the photograph the wedge of dead water which forms in front and a bi-lateral system of eddies upon the rear

[17] G. K. Gilbert, the transportation of debris by running water, *Prof. Pap. U. S. Geol. Surv.*, No. 86, 1914, p. 248, fig. 83.

[18] Jean Brunhes, Sur quelques phénomènes d'érosion et de corrosion fluviales, *Comptes Rendus*, Vol. 126, 1898, pp. 557-560. Le travail des eaux courantes, *Mem. Soc. Fribourgeoise des Sciences Naturelles*, Fribourg (Suisse), 1902, pp. 153-224, figs. 1-10, Sur le rôle des tourbillons dans l'érosion éoliennes, *Comptes Rendus*, Vol. 135, 1902, pp. 1132-1134. Erosion tourbillonaire éolienne, Contribution a l'étude de la morphologie désertique, *Mem. della pontif. Accad. dei Nuovi Lincei*, Vol. 21, 1903, pp. 129-148, pls. 3-4.

[19] Fr. Ahlborn, Hydrodynamische Experimentaluntersuchungen, *Jahrb. der Schiffbautechnischen Gesellschaft*, Berlin, Vol. 5, 1904, pp. 417-453, figs. 1-29.

side (Pl. XXVb). A later study dealing especially with the eddies is even more instructive from the point of view of the desert geologist.[20] Solid bodies of different shapes were drawn through the water and the dead wedge in front and the system of eddies behind shown in photographs. Those which are of most interest in showing the eddies yielded by obstructions which project above the general level of the desert floor have been schematically represented in Fig. 2. These studies seem, therefore, to have supplied an explanation for the peculiar forms of the *Jardangs* described by Hedin and for the porpoise-like features which are produced by wind erosion from a single direction out of the lake beds exposed near Markaz-el-Sherikah in the Libyan Desert (Pls. XIX and XX).



F2|7. Eddies about obstructions of various forms drawn through water (based on Ahlborn).

The ruffled Surface of the Desert Rock.—The experiments and observations above described to show the character of eddies produced in the lower stratum of air over the desert floor, have shown that these eddies have a motion of forward translation which is reflected in layers of sand by the rippled surface. Just as the initial irregularities in the surface of the sand layer induce the formation of eddies in the air layer above, so the irregularities of surface of the desert rock when in coherent masses must likewise be responsible for the formation of eddies above, and these eddies armed with grains of sand are capable of accomplishing erosional work upon an altogether surprising scale. Unlike the eddies over sand-dunes, these are fixed in position,

[20] Fr. Ahlborn, Die Wirbelbildung im Widerstandsmechanismus des Wassers, ibid, Vol. 6, 1905, pp. 65-81, Figs. 1-23. Die Widerstandsvorgänge im Wasser an Platten und Schiffskörpen, Die Enstehung der Wellen, ibid., Vol. 10, 1909, pp. 370-436, pls. 1, 2, 7, 8.

and the erosional work which they accomplish is dependent not alone upon the wind velocity and the charge of sand, but is subject to a steady acceleration as the rock surface takes shape under the eroding process. The character of this surface, which is developed in great perfection at many localities over the great Libyan hamada, can in no way be so well described as by comparison with the ruffled surface of the sea while a fresh breeze is blowing (Pl. XXVa). This surprising likeness is undoubtedly due to a common cause—the readiness of the water surface quickly to take shape in response to the air eddies above it, thus in large degree making up for the brief time interval during which the system of eddies may be considered to be stationary in position.

As regards the rock surface the scale of the rufflings varies between wide limits, and the elongated hollows of the surface in the rock,

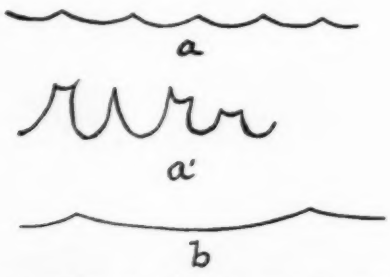


FIG. 3. a, Tranverse section of early ruffles upon the rock surface. a, Mature ruffles. b, Longitudinal section of early ruffles.

as in the water which is suggested for comparison, are of many orders of magnitude occurring together, the smaller superimposed upon the larger (Pls. XXIIIb and XXIV). Owing to the fact that the stationary eddies may continue their shaping influence almost indefinitely, sharply accentuated types of relief pattern are produced for which there is no parallel in the ruffled surface of water (Fig. 3a). It would therefore be proper to speak of early and mature rufflings of the rock surface. In a rock so dense as the finely crystalline limestone which forms the upper layer of the Eocene and likewise the mesa-capping of the Libyan hamada, the polish of the surface becomes so perfect that it gives a blinding mottled glare under the desert sun.

It is interesting to note that rock surfaces similarly ruffled have been produced by the eddies in cataracts, though these surfaces had been seldom brought to the light previous to the modern epoch of gigantic hydro-electric projects. Under the name of a "new process

of fluvial erosion" Lugeon has described such surfaces from the Yadkin River in North Carolina.[21]

Evolution of Ideas Respecting the Origin of Desert Depressions.—*Conception of the Abandoned Sea-Floor.*—Theories of origin of desert depressions which have been offered by geologists, have obeyed the rule of custom in that they have pictured the most familiar scenes to those with whom they originated. Always within easy access to the sea, as European geologists have been, its aspects were familiar, and two noteworthy peculiarities of deserts—the deposits of salts and gypsum and the dunes of sand—were quite naturally brought into prominence with their suggestion of the former presence of the sea.

It is upon the same plan that the simple nomad of the desert has builded his theories, for when Sickenberger asked the Bedouins in his caravan what agent had shaped the country about them, they replied without hesitation, *"El hauer,"* the wind.

The idea that the Great Sahara is the dried bed of an ocean is as old as Erastothenes and Herodotus, and the existence of this ocean was even within five and thirty years a burning question among European geologists, the ingenious theory of Escher von der Linth having held that through preventing the Alpine Föhn the Sahara Sea had brought on the "Ice Age" of Europe. This supposed origin of the Föhn in Africa we now know to be erroneous, but it was not until 1883 that Karl von Zittel, the geologist of the Rohlf's Expedition to the Sahara, was able to lay this specter of the desert and prove that the much discussed Sahara Sea had been a creation of the imagination.[22]

That deserts have originated in arms of the sea is, however, a general notion which has been applied to one desert basin after another and adhered to with varying degrees of pertinacity. To the deposits of salt and sand, which had been brought forward as conclusive proofs, there was generally to be added the evidence of former strands which were clearly the work of water waves. In no small measure the tenacity with which this doctrine was held is to be ascribed to the then generally accepted theory of Ochsenius[23] of the origin of salt deposits. With the aid of this well known theory, much magnified barrier beaches were erected at convenient times so as to transform arms of the sea into interior basins to be subsequently evaporated, the bars being let down again with almost human prevision as the

[21] Maurice Lugeon, Sur un nouveau mode d'érosion fluviale, *Comptes Rendus*, Vol. 156, 1913, pp. 582-584. Le striage du lit fluvial, *Ann. de Géographie*, Vol. 23-24, 1914-15, pp. 385-393, Pl. 11, Figs. 1, 2, 4.

[22] K. A. v. Zittel, l.c., pp. 31-42.

[23] C. Ochsenius, Die Bildung der Steinsalzlager und ihrer Mutterlaugensalze, etc., Halle, 1877, pp. 172.

state of concentration of the salts made such a change either necessary or desirable.

Supposed Tectonic Origin of Desert Basins.—That deserts are often interior basins separated by plateaus or by mountain ranges from the sea was early recognized, and in going farther back to explain their origin, a hardly less common condition was encountered in the existence of displacements about their margins. It was not always taken into account that upon the margins only, where the rock surfaces are well exposed would it be easy, or in fact possible, to prove the existence of dislocations even where present, and too much stress has perhaps in many cases been laid upon the strictly marginal character of the desert displacements. The inevitable result has been that the depressions were rather generally ascribed to profound tectonic movements in which the floors of the basins represent depressed orographic blocks deeply covered by alluvial deposits derived from the surrounding plateau country.

Under the spell of all these ideas deserts have quite generally been pictured as wastes of sand and salt generally lying below the level of the sea. It has been the work of modern explorers to dispel these illusions and to show that the rock desert is, area for area, vastly more important than the waste of sand. According to v. Zittel not more than a ninth of the area of the Great Sahara is sandy desert. Desor supplied a simple classification based upon the terminology of the Arab nomads which though a partial one only, has come into more or less general use.[24] According to him there are: (1) the *plateau desert* or *hamâda* with its rock surface; (2) the *erosion desert* or *Djûf;* and, (3) the *sand desert* or *Erg* (also called *Areg*). To these v. Zittel added a fourth, the *mountain range desert* (Gebirgswüste).[25]

Rôle of Climatic Change.—v. Zittel reached the conclusion that the desert depressions had been produced by the action of running water, being led to this by the indubitable evidence which he discovered of former conditions of higher precipitation, and by the frequent occurrence of now dry water courses or wadis. That deserts may have their origin in atmospheric rather than in purely lithospheric changes is now generally recognized, and this conclusion of v. Zittel though in error in some respects, marked an important advance over existing views in his time. The origin of the present day desert depressions is thus inseparably connected with the question of changes of climate since the last ice age, and the almost world-

[24] E. Desor, Le Sahara, ses differents types de deserts et d'oasis, *Bull. Soc. Sci. Nat. de Neûchatel*, 1864, also Die Sahara, Basel, 1871, pp. 4-25.

[25] K. v. Zittel, l.c., p. 7. To these should now be added the *gravel desert* due to the armoring process, the *salt desert* of which Central Lop is an example, and also the *clay desert*.

wide evidence which has been discovered of a higher precipitation during Pleistocene times has led many to follow the lead of v. Zittel and to ascribe the erosion of the depressions to river action during a pluvial period.

An adequate idea of the important effects of climatic change is only seldom acquired owing to the fact that the changes are so slow as not to be impressive. In a relatively humid country like Europe the effects of increased desiccation are not strikingly brought out unless the accounts be removed in time by long intervals. A comparison of the history of the Roman conquests beyond the Alps with a statement of present conditions is, however, most illuminating.

There is, it would seem, a critical stage in the desiccating process, at which the springs suddenly fail and the lack of rain prevents seeds from germinating. Simultaneously the animal life is either driven away or perishes upon the ground. The recent arrival of this critical stage of desiccation in the Waterberg province of German Southeast Africa, has been most vividly portrayed by a keen observer upon the ground.[26]

Similar but less striking evidences of rapidly increasing desiccation have been supplied from Northern Africa.[27]

Deflation and Consequent Excavation.—Yet except in so far as land barriers have been erected through tectonic movements or as rivers have flowed out to the sea through the ramparts which surround existing deserts, it is difficult to see how running water, be it ever so vigorous in its action, can have played any other than a secondary rôle in the formation of the desert depressions. It may, indeed, bring down the rock material from the higher to the lower levels and spread it in a manner suited to its further lifting and removal by another agent; but since it must always transfer from higher to lower levels, its part in removing material from an inclosed basin must always be nil. An agent competent to remove rock material from the basin and so accomplish its excavation must, quite unlike running water, be able to transport from *lower to higher* levels. The only available agent known to have this property and not excluded by the evidence is the wind, which in desert regions attains a force quite unparalleled within temperate humid regions.

The credit for clearly appreciating the efficiency of wind as an excavating agent in deserts belongs to Professor Johannes Walther,

[26] Advocate Eugène N. Marias, R. J. P., Reitfontein, Waterberg, Notes on some effects of extreme drought in Waterberg, South Africa, *Agricultural Journal of the Union of South America*, February, 1914, reprinted as publication 2342 of the Smithsonian Report for 1914, pp. 511-522.

[27] Frank R. Cana, The Sahara in 1915, *Geogr. Jour.*, Vol. 46, 1915, pp. 342-346. A. Grund, Die Problema der Geomorphologie am Rande von Trockengebieten, *Sitzungsb. d. Wiener Akad.*, Math.-Naturw. Kl., Vol. 115, 1906, Abt. I, pp. 4-5.

who has devoted a lifetime to the study of desert conditions through extended scientific travels. As early as 1890 in his, "Die Denudation in der Wüste,"[28] he showed the competency of desert winds to lift and remove the rock debris prepared for it by the peculiarly effective processes of desert disintegration and decomposition. To this lifting and transporting quality of the wind Walther gave the name *deflation,* and he urged its efficiency as an excavating agent with even greater force in 1900 and again in 1912 in his now classic work upon desert conditions.[29] To his main conclusion he had been led by the studies of Baron von Richtofen upon the great loess deposits of China,[30] which if truly wind deposited, as von Richtofen believed, required that the fine rock material must somewhere have been lifted with the inevitable consequence of hollowed surfaces or depressions.

The effectiveness of Walther's argument consisted in showing that the deserts, whether hamada, Djûf or Erg, are in the main *Abflusslose,* or have interior drainage, and that the wind not only actually raises and transports both sand and dust, but that the latter passes out of the desert in large quantities. This latter argument received strong support in the classic work of Thoulet upon the deep sea deposits, since this showed that the mineral constituents which were found mingled with the organic lime oozes of the ocean, correspond well with the material which is raised and transported in dust storms.[31] From extended measurements made by Udden the size of these particles is found to be generally less than 0.1 mm. in diameter.[32]

The "trades dust" over the Atlantic Ocean west of the Sahara Desert.—In the tenth century the portion of the Atlantic which lies between the Canary and the Cape Verde Islands, or that lying to the west of the Sahara Desert, was known as *mare tenebrosum,* for the reason that the sky was there so often darkened by dust ("Trades dust"). The easterly trades of the region would clearly indicate the origin of the dust in winds blowing out to sea from the great African Desert. This idea was, however, combatted by Ehrenberg upon the erroneous suppositions that the Sahara sands are white and that the

[28] Johannes Walther, *Abh. d. k. säch. Gesellsch. d. Wiss.,* vol. 16, 1890.

[29] Das Gesetz der Wüstenbildung, Reimer, Berlin, 1900, pp. 175, figs. 50. New Edition entirely rewritten published by Quelle und Meier, Leipsic, 1912, pp. 342, figs. 147.

[30] P. von Richtofen, China, Ergebnisse eigene Reisen und darauf gegründeten Studien, Berlin, 1877, vol. 1, pp. 56-125. On the Mode of Origin of the Loess, *Geol. Mag.,* Dec. 11, vol. 9, 1882, pp. 293-305.

[31] M. J. Thoulet, Analyse d'une poussière éolienne et considérations génerales relatives a l'influence de la deflation sur la constitution lithologique du sol océanique, *Ann de l'Institut Océanographique,* Paris, III, fasc., 2.

[32] J. A. Udden, Erosion, Transportation, and Sedimentation performed by the Atmosphere, *Jour. Geol.,* vol. 2, 1894, pp. 318-331.

winds of the region blow in the contrary direction. The proof that dust over this portion of the Atlantic is in reality derived from the Sahara region has been clearly established by Hellman upon both meteorological and geological grounds.[33]

The Beginning of a Change in American Opinion.—It cannot be claimed that Walther's views, though so convincingly presented and supported by such a wealth of observation, brought any early change in the prevalent notions respecting the origin of desert depressions. In America, where large monographs had been published upon the geology of the vast interior basins, the influence of the wind as an excavating agent had been entirely overlooked. Gilbert in a carefully guarded statement covering a few pages only, has quite recently suggested that certain hollows occupied by small lakes within the Great Plains area lying to the east of the Rockies, may possibly have had their origin in lifting and transportation[34] of loose materials by the wind. (The greater vegetation of American as opposed to Old World deserts may perhaps in part account for some difference in viewpoint.)

These small depressions are, however, more to be compared with those which are so common a feature of the Karroo and Kalahari in Africa, which as Passarge has shown, while somewhat diverse in their origin, have in all probability arisen through wind action assisted by the movements of the vast herds of large animals which inhabit the region.[35] A far more important paper dealing with the subject of excavation within the American desert regions, is that of Cross, who shows that soils in the mountains of Colorado are probably eolian in origin and derived from the plateau country to the westward. After describing the obvious large measure of deflation in portions of Utah, he concludes that the effective degrading power of the wind has not been fully appreciated by those who have studied the desert regions of the west.[36]

[33] G. Hellman, Ueber die auf dem Atlantischen Ozean in der Höhe der Kapverdischen Inseln haüfig vorkommenden Staübfälle, *Monatesber. Berl. Akad. Wiss.*, 1878, pp. 364-403. Also, Ueber die Herkunft der Staübfälle im "Dunkelmeer," Sitzungsber. kgl. preuss. *Akad. Wissensch.*, vol. 14, 1913, pp. 272-282.

[34] G. K. Gilbert, Lake Basins created by Wind Erosion, *Jour. Geol.*, vol. 3, 1895, pp. 47-49.

[35] S. Passarge, Die pfannenförmigen Hohlformen der südafrikanischen Steppen, *Pet. Mit.*, 57, 1911, II, pp. 57-61, 130,135.

[36] Whitman Cross, Wind Erosion in the Plateau Country, *Bull. Geol. Soc. Am.*, vol. 19, 1908, pp. 53-62, pls. 3-4.

It is probably not well known that Professor Walther as long ago as 1892 drew attention to the effect of wind erosion in the American Deserts (J. Walther, Die nordamerikanischen Wüsten, *Verh. Gesell. f. Erdkunde z. Berlin*, vol. 19, 1892, pp. 1-14 (in separate) Also, The North American Deserts, *Nat. Geog. Mag.*, vol. 4, 1892, pp. 163-176; and A comparison of the deserts of North America with those of North Africa and northern India, *Science*, vol. 19, 1892, p. 158.

Island Mountains as Erosion Residuals.—Fourteen years after the appearance of the "Denudation in the Desert" the same general explanation of the origin of desert depressions through wind erosion was independently brought forward by Passarge with emphasis upon new and important considerations, all based upon extended personal studies within the great deserts of South Central Africa.[37] "The island mountain landscapes," wrote Passarge, "consist of wide plains, actual plains and not flat hilly country, out of which individual mountains rise like islands from the ocean." As described by Passarge from Bechuana Land, the island mountains may be mere knolls or they may be high mountain masses thousands of meters in altitude, but always the floor of the plain meets the steep slope of the islands without any perceptible intermediate gradations of curvature. These island mountains Passarge found to consist uniformly of granite or of other massive and relatively resistant rock, whereas the rock of the surrounding desert floor was sandstone, clay, schist, etc., but in any case softer rocks or those which by reason of lamination planes or fissures were more easily eroded. It thus appeared that the island hills were the unreduced residuals of a denuded area, with the main surface of denudation a featureless plain quite independent of the dip of the strata underlying it. (See author's examples in Pl. XXVI.)

The Rock Floor of the Desert Plain.—As already stated Passarge found the agent of denudation to be the wind, and to meet the objection that there was no obvious cause for the leveling of the plain, he called in the infrequent rains, which according to his view tended to fill in the depressions which were hollowed out by the wind.

The Swedish explorer of Central Asia, Dr. Sven Hedin, in discussing the origin of the Tarim basin, has likewise held the view that water deposition has counteracted a supposed hollowing effect of the wind. Thus he says:

"Theoretically a regular and powerful atmospheric current, blowing across a region in which it does not deposit the drift sand it carries with it, but only excavates, is indeed able to produce a considerable depression. But in the Desert of Lop this result is counteracted by the quantities of water which fill the deepest parts of the basin with solid material, and bring them up *au niveau* with the country adjacent. What therefore during a certain period has been gained through the erosion of the wind, is lost again by the deposition, through the assistance of the water, of sand and silt. Precisely the same amount of solid material as is carried away in one place is accumulated in

[37] Siegfried Passarge, Die Inselberglandschaft im tropischen Afrika, *Naturw. Wochenschrift*, N. F., vol. 3, 1904, pp. 657-665. Rumpfflächen und Inselberge, *Zeitsch. d. deutsch. Geol. Gesellsch.*, vol. 56, 1904, pp. 193-215. Die Kalihari, Reimer, Berlin, 1904, pp. 822 and atlas.

another, the result being a flat alluvial expanse instead of a conchoidal depression.[38]

It is evident, however, that the main erosion of the Tarim basin, if it is to be ascribed to wind erosion, has not been accomplished under the present but under former different conditions of climate which the researches of Huntington[39] show have existed in the past and will again recur. Hedin, who has appreciated this fact, says:

"When the migratory lake of Lop-Nor shall finally have disappeared, and the extreme tentacle of the Tarim shall have died away in the sand higher up its course than it does now, the wind will then be able to excavate the desert of Lop unchecked, producing a deep depression, the center of a never ending aridity."[40]

The appearance of Passarge's monographs upon the deserts of South Africa so impressed Professor Davis, who had developed his geographic cycle without reference to the vast arid regions, that in his "The Geographic Cycle in an Arid Climate"[41] he adopted Passarge's ideas concerning the formation of level-floored basins under arid conditions through the action of wind erosion supplemented by running water; the level of the floor having no necessary relation to any base-level as this term is understood in its application to humid regions. Mawson has supplied other examples from the Australian deserts.[42]

The traditional view which has held that desert basins are tectonic in their origin—that the depression is the result of the settlement of one or more orographic blocks—naturally led up to the view that the evenness of the desert floor was always to be explained through alluviation from surrounding heights. Being thus a broad surface of deposition, the surface of the rock was assumed to be covered to considerable depths. Passarge's discovery that the floor of the plain was often of rock and that the surface deposits were in any case comparatively thin, was, however, not an isolated one and has been confirmed by similar observations in other desert regions, some of which antedate by many years the date of Passarge's first monograph.[43] McGee, who had been

[38] Sven Hedin, Scientific Results of a Journey in Central Asia, 1899-1902, vol. 2, 1905, p. 460.

[39] Ellsworth Huntington, Lop-Nor—A Chinese Lake, *Bull. Am. Geogr. Soc.*, vol. 39, 1907, pp. 65-77, 137-146. The Pulse of Asia, New York, 1907, pp. 415, maps and plates. The Rivers of Chinese Turkestan and the Desiccation of Asia, *Geogr. Jour.*, vol. 28, 1906, pp. 352-367.

[40] Hedin, l.c., p. 461.

[41] W. M. Davis, *Jour. Geol.*, vol. 13, 1905, pp. 381-407.

[42] Douglas Mawson, Geological investigations in the Broken Hill Area. *Mem. Roy. Soc. So. Australia*, vol. 11, 1912, pp. 224-223, pl. VI. 2.

[43] W. J. McGee and W. D. Johnson, Seriland, *Nat. Geogr. Mag.*, vol. 7, 1896, pp. 127-128. W. J. McGee, Sheetflood Erosion, *Bull. Geol. Soc. Am.*, vol. 8, p. 91, C. R. Keyes, Geological Structure of New Mexican Bolson Plains, *Am. Jour. Sci.*, vol. 165, 1903, pp. 207-210.

forced by this discovery in the deserts of southwestern New Mexico and Northern Mexico to abandon the idea of an alluviated plain, sought to explain the even surface of the rock by sheetflood erosion, though this could obviously not apply to all parts of the desert floor.

The Pebble Armor of the Desert. It was Penck who first suggested the name of armoring (*Panzerung*) of the desert as a result of lighter and finer materials being carried away through deflation or wind transportation, while coarser or heavier fragments are left behind.[44] It was Walther, however, who by full descriptions and many excellent photographs showed the great importance of the process over vast areas in the arid regions.[45] In by far the larger number of instances "pebbles" composing the armor are harder nodules such as fossils, flints or concretions which are derived as a residual from higher beds that have been disintegrated and removed by the wind. Such thin veneers over rock have no doubt in many instances been taken for the surface portions of thick deposits of sediment. (See Pl. XVII.)

Planorasion. Though the desert floor approximates to a plane surface, it is by no means true that it is always level. This fact has been brought prominently forward by Dr. C. R. Keyes,[46] though his statements have been sharply challenged, and the records of well borings seem to show that the rock floor of desert basins is less common a feature in the Great Basin region than Keyes has claimed. Working in conjunction with the processes of desert disintegration the wind acts as an abrading and eroding agent which, unlike running water, works up-hill. This process, termed by Keyes *planorasion,* in the early stages of its action may grade a slope as steep as 4% (claimed to be not uncommon along the lines of railway crossing the western deserts of the United States), but this is probably near the limit of steepness of slope which planorasion can erode as a plane.[47] Sheet-

[44] A. Penck, Die Morphologie der Wüsten, Geogr. Zeitsch., vol. 15, 1909, p. 551. The result is a "gravel" desert. See ante, p. 42.

[45] Das Gesetz der Wüstenbildung, Edition of 1912, pp. 186-195.

[46] C. R. Keyes, Geological Structure of New Mexican Bolson Plains, *Am. Jour. Sci.*, vol. 165, 1903, pp. 207-210. Rock-Floor of Intermont Plains of the Arid Region, *Bull. Geol. Soc. Am.*, vol. 19, 1908, pp. 63-92, pl. 5. Geologic Processes and Geographic Products of the Arid Region, ibid., pp. 570-575, pls. 38-41. Erosional Origin of the Great Basin Ranges, *Jour. Geol.*, vol. 17, 1909, pp. 31-37. Certain Features of Eolic Gradation, Cong. Géol. Intern. 12me Sess., Canada, 1913, pp. 1-5 (advance copy). These views of Dr. Keyes have been contested especially by Tolman (*Jour. Geol.*, vol. 17, 1909, pp. 136-163) and Tight (*Am. Geol.*, vol. 36, 1905, pp. 271-284) on the ground that desert floors are not generally of rock but are often overlain by considerable deposits of alluviated material.

[47] Barron has described from the Arabian Desert a distinctly inclined surface of Eolian planation which bevels the strata (T. Barron, The Topography and Geology of the District between Cairo and Suez, Surv. Dept. Egypt, 1907, pp. 19, 115-116).

flood erosion, according to Keyes, instead of producing the planed surface of the desert floor is rather a direct consequence of it. The levelled floors of the South African deserts which have been described by Passarge, with little doubt illustrate later stages in the operation of the process of planorasion; and it is doubtful if the aggradation by running water invoked by Passarge is at all essential in order to account for the level surface. Moreover, as Keyes shows by examples, the wind is a far more potent agent in evening out by deposition any hollows of the surface than is running water.

The Possible Effect of Caliche Armor.—Woodward in describing the great flat floors in the arid region of Western Australia, has shown that truncated schists are either at or near the surface, the truncation in his view being due to wind erosion and the level determined by the level of ground water sufficiently near the surface for capillary attraction to conduct the water to it and hold the material against the action of the wind.[48] Jutson who has since investigated the same region, has supplied an interesting explanation of the formation of these plains.[49] The underground water in being drawn up to the surface brings with it dissolved mineral matter which is deposited in a surface layer to form a hard protective cap, which may vary in thickness from a few inches to a few feet. Jutson's idea seems to be that the originally flattish surface provided with protective armor of this sort becomes broken through locally by gully formations at the time of infrequent but violent desert rains, and that thereafter the cap is progressively undermined by deflation so that in time a new plain develops at the new base level which eventually becomes armored as was the first.

Two recent papers which have revived with ingenious elaborations the older theory of formation of desert floors wholly as a result of water erosion and alluviation, while ignoring the deflation process, are those of Paige[50] and Lawson.[51]

Relative Importance of Deflation and Alluviation.—Whatever may be the relative measures of deflation and alluviation within desert basins—and we are still very far from a definitive settlement of the question—the dust clouds so generally to be observed upon the leeward margins of the basins and the eolian soils outside, show only too

[48] H. P. Woodward, The dry lakes of Western Australia, *Geol. Mag.*, (4) Vol. IV, 1897, pp. 363-366.

[49] J. T. Jutson, An outline of the physiographical geology of Western Australia, Bull. 61, Western Australia Geological Survey, 1914, pp. 142-158.

[50] Sidney Paige, Rock-cut surfaces in the desert ranges, *Jour. Geol.*, Vol. 20, 1912, pp. 442-450.

[51] A. C. Lawson, The epigene profiles of the desert, *Univ. of Calif. Pubs., Dept. of Geol.*, Vol. IX, No. 3, 1915, pp. 23-48, pls. 1-2.

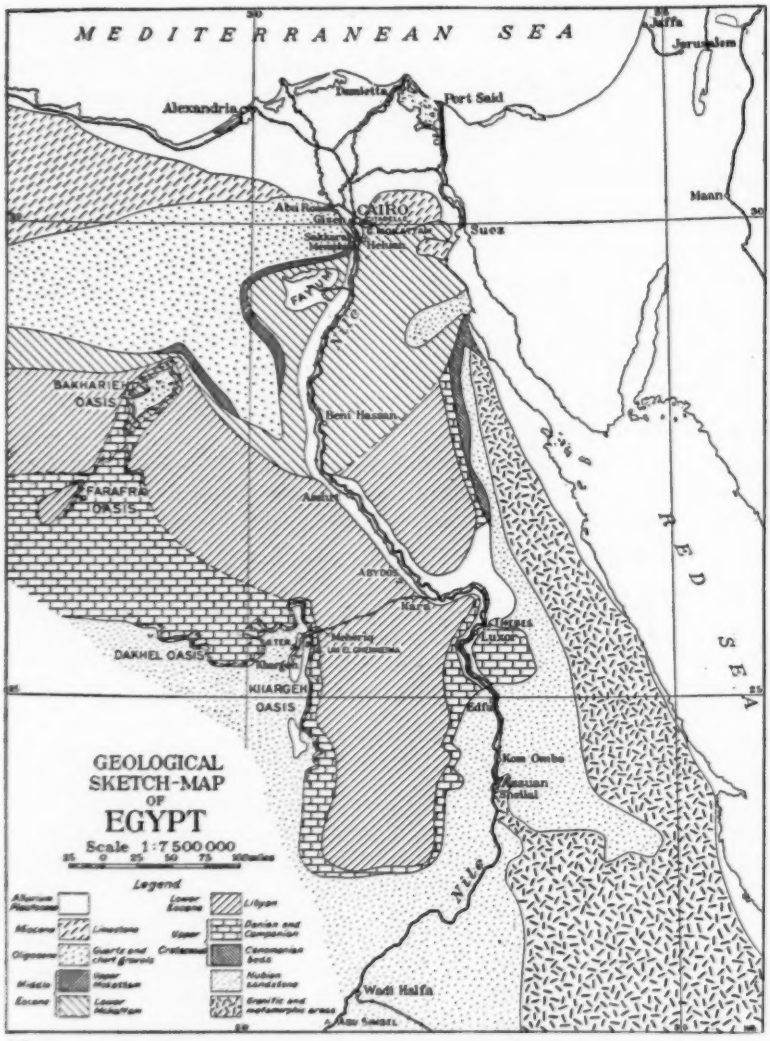


FIG. 4—Geological Sketch-Map of Egypt (after Hume).

clearly that if the floors have been raised through alluviation, as has so generally been assumed, the measure of this work must have been many times greater than that indicated by the thickness of the floor deposits themselves, a fact amply confirmed by the coarseness of the alluviated materials.

An apt illustration of what is meant is furnished by the Oriental

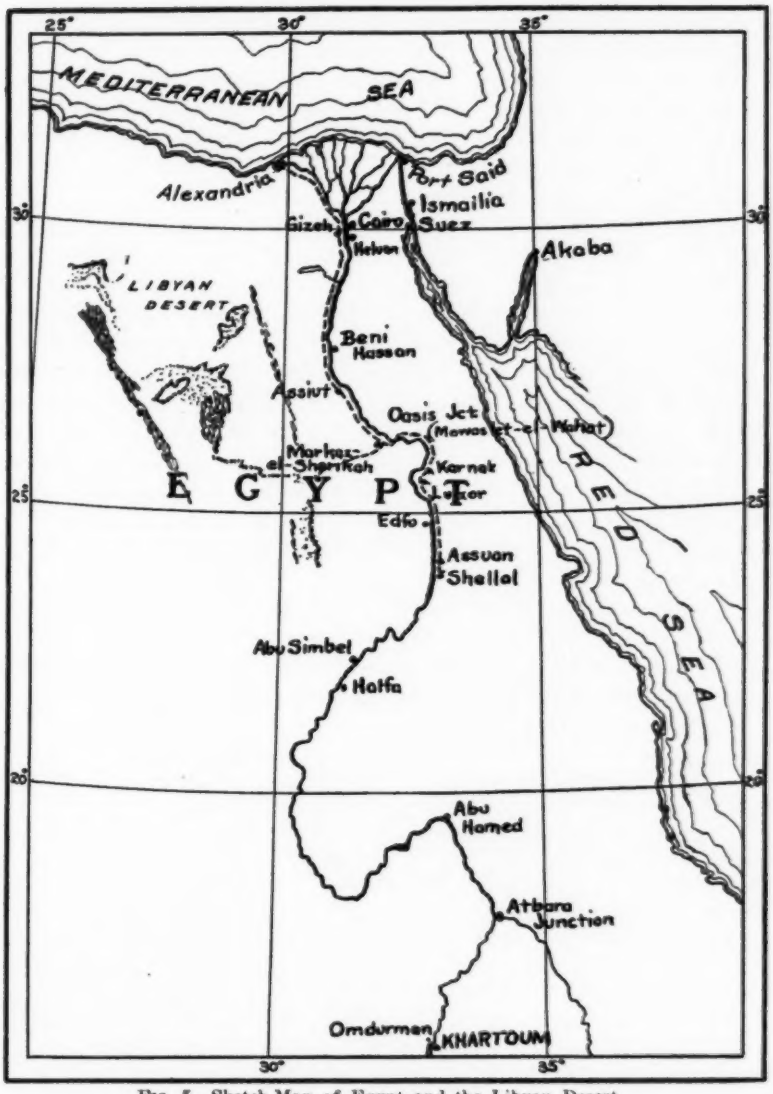


FIG. 5—Sketch-Map of Egypt and the Libyan Desert

threshing process, where the bulk of the material—the chaff—is carried away by the winds, leaving behind upon the threshing floor a selected residue only, and likewise of the heavier and coarser materials. In the case of deserts, this residue having much of it been brought down from the surrounding highlands through the process of alluviation,

easily gives the impression that the desert floor has been raised by alluviation, though it may have been actually lowered through deflation.

THE OASIS DEPRESSIONS OF THE LIBYAN DESERT.—*Physiographic Simplicity of the Libyan Desert.*—Whereas the Arabian Desert lying eastward from the Nile toward the Red Sea presents some variety of topographic feature and a number of strongly developed valleys tributary to that river, the Libyan Desert to the westward of the Nile is a broad featureless plateau or *hamada,*[52] which rises nearly 1,000 feet above the bottom of the Nile rift, a plateau which is locally interrupted by more or less flat-bottomed basin-like depressions obviously excavated out of the hamada. These basins are relatively few in number and often are of quite moderate dimensions compared to those of the plateau as a whole. One of them, however, the Great or Kharga Oasis, covers a number of square degrees. The other oasis depressions are quite largely included in the rectangle bounded by the meridians of twenty-five degrees and thirty degrees east longitude and by the parallels of twenty-five degrees and thirty degrees north latitude (figs. 4 and 5). They are known as the Dakhla, Farafra, Baharia, and Siwa Oasis, the latter far to the northwestward of the others and correspondingly difficult of access by travelers (fig. 6). To those mentioned should perhaps be added the Fayûm, which is connected with the Nile rift, the Wadi Natron, and Araj. The depths of each of these basins and the elevations measured from mean sea level of the rim and floor have been given as follows:

Oasis.	Elevation of Floor in Meters	Elevation of Rim in Meters	Depth of Basin in Meters
Araj	—70	+120	190
Fayûm	—44	+340	384
Siwa	—25		
Wadi Natron	—28	+205	207
Kharga	—18	+448	466
Dakhla	+58	+485	391
Farafra	+26	+320	294
Lake Sitra	—25		
Baharia	+134	+311	177

With the exception of these basins the Libyan hamada may be considered the most arid area upon the globe, since it is almost absolutely devoid of water. The hamada is actually little explored except along the established caravan routes connecting the basins. These basins themselves have, however, each been investigated and made the subject

[52] George Steindorff, Durch die Libysche Wüste zur Almonsoase, Land-und Leute-Monographien zur Erdkunde. Velhagen und Klasing. Leipzig, 1904.

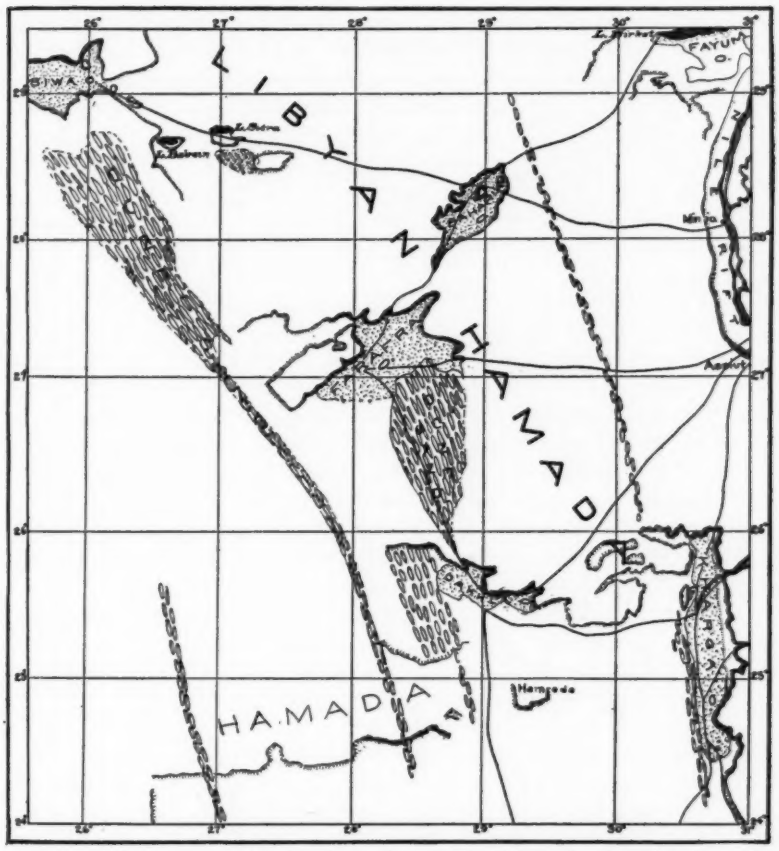


FIG. 6. Sketch map showing the depressions in the Libyan hamada, based on the map by the Egyptian Survey

of a special report, the Siwa oasis by the Public Works Ministry,[53] and the others by the Egyptian Survey Department.[54]

A crude attempt to present in vertical section the shape and pro-

[53] Report on Siwa Oasis, 1900.

[54] Kharga Oasis, its Topography and Geology, by John Ball, 1900.
Dakhla Oasis, its Topography and Geology, by H. J. L. Beadnell, 1901.
Farafra Oasis, its Topography and Geology, by H. J. L. Beadnell, 1901.
Baharia Oasis, its Topography and Geology, by J. Ball and H. J. L. Beadnell, 1903.
See also, Topography and Geology of the Fayûm, by H. J. L. Beadnell, 1903; An Egyptian Oasis (Kharga), London, 1909, pp. 248; Ellsworth Huntington, The Libyan Oasis of Kharga, *Bull. Am. Geogr. Soc.*, vol. 42, 1910, pp. 641-661; Wm. H. Hobbs, A Pilgrimage in Northwestern Africa with Studies of Desert Conditions, *Geogr. Rev.*, Vol. 3, 1917, pp. 337-365.

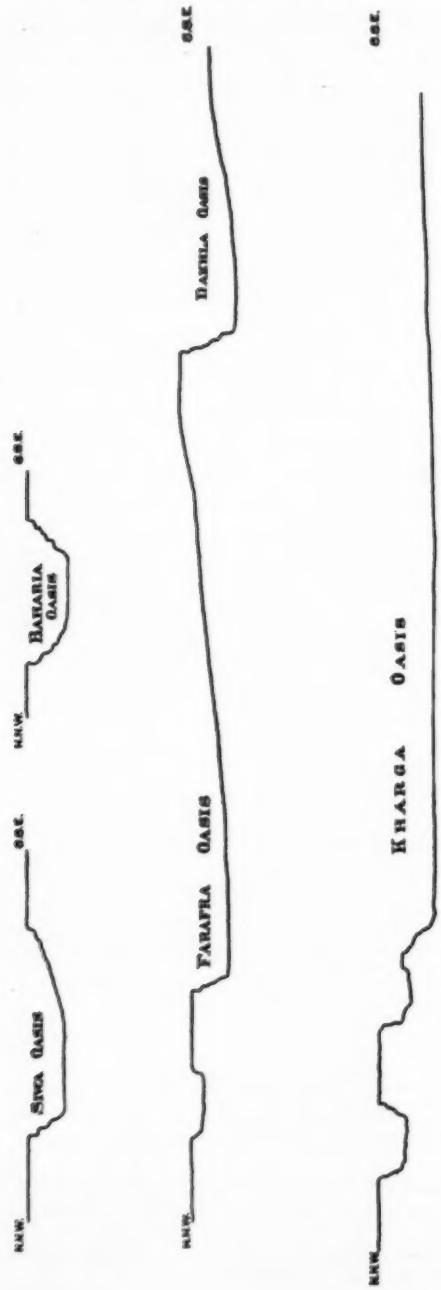


FIG. 7.—Rough sections across desert depressions

portions of the basins, has been made in fig. 7, with gross exaggeration of the vertical scale. From these and from the map it will be apparent that the northerly and northwesterly margins of the depressions when compared to the opposite walls are remarkably steep, and that in the larger depressions the basins deepen gradually in the direction of these margins. This fact is believed to be one of significance. The Government map indicates further that heavy sand dunes have formed upon the hamada on the south of the smaller depressions when a southern wall is indicated, and that the sand dunes starting from the southern margins of the depressions trail off to leeward to distances many times the diameter of the basins themselves. Of the smaller basins the floors are notably flat and are generally formed of the upper water-bearing layer of the Nubian Sandstone.

Origin of the Depressions.—All the physiographic peculiarities of the basins appear to indicate their origin through the process of deflation, that is to say, to the lifting and transporting action of the wind, which here blows throughout the year from directions included within an extremely narrow sector a few degrees only to the west of north. It is highly probable from the arrangement of sand dunes that farther to the westward the constant winds approach more nearly to the northwesterly direction. The origin of the depressions through the agency of running water is inconceivable, for the reason that water has not the power when free flowing to transport material from lower to higher levels, here absolutely essential in order to accomplish the excavation.

Walther has already invoked the deflation theory of origin to explain the depressions, without, however, making use of the evidence which is afforded by the official map,[55] here printed in outline. Says Walther, "Yonder the hollows, here the areas of deposition are filling, and between both the wind bride marches. Whoever recognizes this connection and has followed it searchingly, must come to the conclusion that the deflation of the wind is the determining factor in the fashioning of the desert relief."

What gives to the Libyan desert its special fitness as an area within which the problem of the sculpturing agent may be decisively solved, is above all its excessive aridity and the fortuitous circumstance of an essential constancy in flat dip of rock beds and in wind direction. The criteria which seem to be decisive in the solution, are (1) the orientation of the unsymmetrical basins with regard to the wind direction, (2) the location of the sand and dust accumulations to the leeward of the basins, and (3) the halting of the process of excavation in the

[55] Johannes Walther, The various articles of earlier years are summarized in "Das Gesetz der Wüstenbildung" 2te. Aufl., 1912; General discussion, pp. 164-179, special application to the Libyan depression, pp. 205-211.

larger and maturer basins so soon as a water bearing formation has been laid bare. (Nubian Sandstone).

Orientation of the Basins with Reference to Wind Direction.—The several basins appear to represent varying degrees of maturity in the excavating process, the smaller and shallower ones being in general the younger. Such are Siwa, Baharia and the diminutive depressions of Araj, Lake Sitra and Lake Bahrein. Farafra and Dakhla oases obviously represent more mature stages, while Kharga with its large dimensions and pronounced asymmetry, is by far the most mature of all.

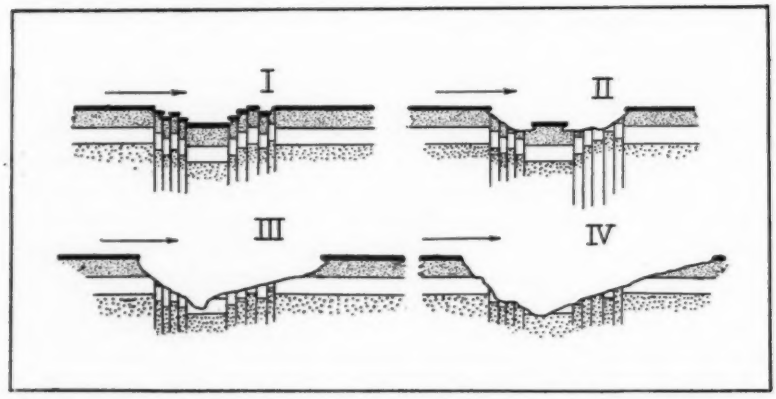


FIG. 8.—Stages in the excavation of desert depressions by deflation initiated by local faulting

Passing over for the present the cause of the localization of the basins, we note that the smaller depressions are bounded throughout by steep walls, though these are much more precipitous and quite generally inaccessible upon the windward (north northwesterly) side. When the shaping of the basin is ascribed to deflation aided by the flying sand, the steep wall upon the windward side is readily explained by the eddy which is always turned under and backward above each hollow of the ground. Such an eddy would result in sapping and should produce the steep cliffs characteristic of that process in a wide range of geological phenomena. No such eddy should develop upon the leeward margin of the depression, where abrasion and deflation of more normal type would take its place and develop a backward sloping surface (with regard to wind), which would grow flatter as the area of the basin is enlarged.

Significant Position of the Coarser Excavated Material.—The areas of dune sand which lie to the leeward of the Siwa and Farafra de-

pressions, and the similar small dune area connected with Lake Sitra, point strongly to the derivation of this sand from the excavation of those basins with which they are geographically connected. The long, narrow trail of dunes strung out upon the hamada toward the Nile valley from the central group of depressions, with little doubt has its beginning in an unknown basin lying within the great unexplored area to the westward of the Fayûm. Another unknown basin probably lies to the westward of the Dakhla or Farafra oasis.

Deposition of the Loess as the Cotton Soil of the Sudan.—In addition to the sand which moves along the desert surface by saltation and is carried to very moderate heights only, the finer dust often reaches to considerable altitudes. Traveling with a relatively high velocity, this finer material is not permanently halted in its course until it encounters a moist surface. In the region under consideration such a moist surface is first met with where the tropical rains make their greatest advance to the northward, a limit which is reached some 150 miles to the northward of Khartoum. This loess deposit is, according to Mr. G. W. Grabham, the Geologist to the Sudan Government, of a thickness increasing to the southward and sometimes as much as one hundred feet in depth. It is the soil found suitable for cotton growing upon irrigation.[56] One of the dust storms arriving at Khartoum from across the Blue Nile to the northward is represented in Plate XXIIa.

Arrest of the Downward Excavating Process in the Basins When the Water-Bearing Sandstone Has Been Laid Bare.—The deflation process is arrested when rock layers containing water are encountered. The series of rocks represented, range from the Nubian Sandstone, which rests directly upon granite and metamorphic rocks, up through Upper Cretaceous and Tertiary beds to terminate in a limestone of Miocene Age. As all are gently tilted toward the northward, the capping of the Hamada over a large part of the Libyan Desert is the Lower Eocene or Libyan limestone (fig. 8). The depressions are generally excavated out of this superior formation, the Upper Cretaceous beds, and a considerable thickness of the Nubian Sandstone, until a water-bearing layer is reached.

Cause of Localization of the Desert Depressions.—In the writer's belief the most probable cause of the localization of the basins, is to be found in local faulting amounting in the aggregate to some hundreds of feet, though distributed through a considerable zone and represented by small individual displacements upon each fault plane—a cause

[56] G. W. Grabham, Wells of the Northeastern Soudan, *Geol. Mag., N. S.*, Dec. V. vol. 6, 1909, pp. 265-267, fig. 1. See also Sir William Willcocks, Egypt Fifty Years Hence, address delivered at a meeting of the Khedivial Geographical Society, Cairo, March 15, 1902. Printed under title, The Restoration of the Ancient Irrigation Works on the Tigris River, Cairo, 1903, pp. 43-71.

which may likewise be appealed to for explanation of the rift of the Nile itself. Eduard Suess[57] was one of the first to draw attention to the importance of meridianal fractures in fixing the course of the Nile rift. Passarge[58] has since supplied a much more comprehensive treatment of the tectonic lines of the African Continent. The reports of Barron and Hume,[59] Ball,[60] and Hume,[61] covering the Arabian Desert and the Desert of Sinai, show how for these areas the course of each wadi is controlled by dislocations. This control by fractures is given expression by the official maps in numerous localities.

In ascending from the Nile rift along the wadi from Qara by the railway to Kharga Oasis, the existence of a layer of large concretions permits one to note the presence of hundreds of faults of small displacement (usually from one to two feet) with sub-equal space intervals.

Within the Kharga Oasis Ball has called attention to the presence of faults. In summarizing he says, "From the foregoing brief discussion of the tectonics of the oasis, it will be apparent that the whole area has undergone disturbance resulting in folding and faulting; and since the faults affect the highest rock on the plateau, it is clear that they took place since the deposition of all the strata which now occur in the oasis."[62]

It is not necessary that the disturbances of the strata which have been responsible for the excavation of the oases within the Libyan Desert, should be essentially different from those which the writer observed especially upon the eastern margin of the hamada toward the Nile rift. In order to understand how small displacements can initiate excavation within the hamada, it is necessary to take into account the thin capping of "glass hard" limestone which is here underlain by a softer limestone with interbedded layers of marl and clay, the entire series ranging from 76 to 136 meters in thickness. This is in turn underlain by the gray and green clays of the Esna Shales. The thin but resistant mesa cap is but slowly worn away by the desert sand blasts, and is polished until it glares in the sun like burnished metal. Once lifted by local faulting the cutting sand attacks

[57] E. Suess, Die Brüche des östlichen Afrika, Denksch. *Wiener Akad., Math. Naturw. Kl.*, vol. 58, 1891, pp. 555-584.

[58] S. Passarge, Die Kalihari, Berlin, 1904, pp. 79-80.

[59] T. Barron and W. F. Hume, Topography and Geology of the Eastern Desert (Central Portion), 1902.

[60] John Ball, A Description of the First or Aswan Cataract of the Nile, 1907. See also, H. J. L. Beadnell, The Cretaceous Region of Abu Roash near the Pyramids of Giza, 1902.

[61] W. F. Hume, The Topography and Geology of the Peninsula of Sinai (Southeast Portion), Surv. Dept. Egypt, 1906, pp. 29-37.

[62] John Ball, Kharga Oasis, Its Topography and Geology, Surv. Dept. Egypt, 1900, pp. 95-100; See also J. H. L. Beadnell, An Egyptian Oasis, pp. 53-54.

the soft underlying shales, a process which may be observed in operation upon the eastern scarp of the Kharga Basin, for when once exposed the soft underlying shales are removed by deflation, thus sapping the limestone cap.[63]

The stages likely to develop in the excavation of a desert basin as the results of such conditions, are set forth in Fig. 8, in which stage III is represented to-day by the small oases Siwa and Baharia, and stage IV by the more mature types Farafra, Dakhla, and Kharga. We have chosen to represent marginal dislocations about a small depression, but the evolution can just as well be accomplished wherever small local disturbances are found, the one essential being that the sand blast be allowed to make its attack upon the soft shales beneath the hard limestone capping. Once laid bare, this loosely coherent material requires no considerable disintegration, but is lifted by the wind and carried away to leeward. Hume has recognized the importance of this process when once the capping has been removed.[64]

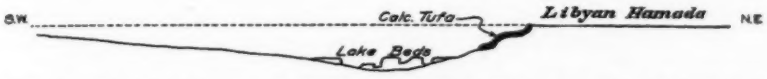


FIG. 9.—Schematic diagram to show position of lake deposits and calcareous tufa in Kharga depression

Former Climatic Strophe of the Libyan Desert.—If the basins within the Libyan Desert are to be regarded as the work of the wind which lifts and removes the material from beneath the hamada capping, and eventually also the disintegrated fragments of the latter; the major portion of the work must have been accomplished, not in the present arid cycle of the region, but in a former period of great aridity, separated from the present by a humid period. The evidence of this humid strophe is furnished by the calcareous tufa on the eastern scarp of the Kharga Basin and by other similar formations of cataract origin nearer the Nile, and also by extensive lake deposits, the remnants of which are still to be found in the bottom of the Kharga depression. These remnants of lake deposits have by the constant northerly winds been carved into asymmetrical north-south ridges (Fig. 9). The lake in which they were laid down must have had according to Beadnell at one time a depth of some 85 meters, and for a considerable period a depth of 70 meters. The deposits contain fresh water shells, bones of the ox and of either a horse, donkey or zebra, as well as pottery dating from the Graeco-Roman period.[65] The deposits of tufa which occur on the capping of the hamada and extend down the Refûf Pass

[63] Ball, l.c., p. 95.

[64] W. F Hume, The South West Desert of Egypt.

[65] Beadnell, An Egyptian Oasis, ch. viii.

into the oasis, inclose beside numerous fresh water shells, casts of leaves of deciduous trees, among them those of the oak, as was first pointed out by von Zittel.[66] There seems also to be evidence in the dregs in exhumed pottery vessels that the vine was grown in the oasis, evidence which receives support from some of the inscriptions upon monuments in the valley.

Ball's difficulty in explaining the origin of these basins we believe is largely due to his failure to conceive the possibility of alternations of climate within cycles, passing from arid through humid to arid conditions again; a conception that now receives support in many fields and nowhere more than in that of glaciers. Ball says, referring to the tufa deposits;[67]

"As these tufa deposits were formed after the oasis had acquired substantially its present form, we must infer that the main excavating agency in past times cannot have been the sand blast, for this would be irreconcilable with the idea of a then prevalent moist climate.

"It is therefore most likely that the excavation was begun by the action of water, and after this ceased, owing to a total change in the climatic conditions, the work was continued and is being continued by the agency of wind and sand."

This failure to appreciate the alternations of climate (strophes) is, in the belief of the writer, responsible for much misconception among archaeologists and geologists alike. For example, the simple and natural explanation for the abundant big game fauna depicted in the wonderful mural decorations of the Mastabas of Ti and Ptahhotep at Sakkâra on the eastern margin of this desert, is that a wild animal life, not unlike that found to-day in the Uganda to the southward once lived here in a humid climate. We know that a large stream poured its waters over the brink of the hamada into the great oasis, which then held a large fresh water lake. Upon this assumption only is it possible adequately to account for the much larger population and the high degree of civilization which then existed there.[68]

[66] Geologie der Libischen Wüste, 1883.

[67] l.c., p. 101.

[68] Geographical Review, vol. iii, No. 5, May, 1917, p. 344.

MEMOIR OF CLEVELAND ABBE

ALFRED JUDSON HENRY

Cleveland Abbe was the oldest of a family of seven children:

Cleveland	1838	
Walter	1841	
William	1843	Wounded at Gettysburg
Charles	1849	
Robert	1851	
Helen	1853	
Harriet	1855	

of whom all are living save his brother William, who died from the after-effects of the wound received at Gettysburg. Robert became a skillful and famous surgeon of New York; Walter, his favorite brother, was for many years head chemist of the Atlantic White Lead works; and Charles, a skillful inventor, who died in 1917, was for some years an assistant examiner in the U. S. Patent Office.

Cleveland Abbe was faithfully helped and supported throughout the strenuous Seventies and Eighties by his first wife, Frances Neal, and his last years were almost a resurrection for him in the care and love bestowed on him by his second wife, Margaret Percival, of St. Kitts, B. W. I.

He died after a somewhat extended illness at his home in Chevy Chase, Md., October 28, 1916, being almost 78 years of age. His boyhood was spent in New York, with the exception that most of the summers were spent at the old family home near Windham, Conn. He was undoubtedly nearsighted at birth, for he could never see to play ball and spin tops as other boys did, but this nearsightedness was not discovered until he was nearly fourteen, and it was not helped by a Fourth of July experience with a well-charged anvil that seemingly refused to go off until he held his eyes close down over it. He received the charge almost full in his eyes and for a while his sight was despaired of. Probably his nearsightedness predisposed him for reading, of which he was always inordinately fond, though not along the lines prescribed by the school curriculum. During his summers in Windham he should have been helping his grandfather, Moses Cleveland Abbe, run the farm, but he preferred to lie out in the warm July sun and observe and study the clouds floating overhead. At the time this did not create a favorable impression. While a keen observer and reasoner in all the natural sciences, he undoubtedly took most interest at this time in the weather. He was early impressed with the idea that much of the weather knowledge then current was faulty

and this impression was doubtless confirmed upon reading the occasional popular articles which appeared in the daily papers, often contributed by the leaders in meteorological thought of that period.

In the summer of 1858 there appeared in Runkle's Mathematical Monthly the first of a series of classic articles by William Ferrel, entitled "The Motions of Fluids and Solids on the Earth's Surface." Abbe was quick to realize the epoch-making nature of these articles, also that many of the difficulties that had hitherto existed in the generally accepted beliefs had been overcome. It is difficult properly to estimate the influence that the writings of William Ferrel had upon the mind of young Abbe. Fortunately for Meteorology, his mind at that time was in the formative period.

After graduating from the College of the City of New York in 1857, Abbe was engaged in tutoring for a short season: then wishing to continue his studies in astronomy, he studied at Ann Arbor under Brünnow and later at Cambridge under Gould. At the time he went to Cambridge, Dr. Gould was perhaps one of the most active and influential astronomers in the United States. A short time previously he had taken charge of longitude operations in the Coast Survey and it was principally as an aid in that Survey that young Abbe received his first field experience in astronomical work.

In April, 1861, he answered the first call for volunteers to defend the Union:—naturally, since in his veins ran the blood of participators in all the wars of the colonies and all the battles of the Revolution save those of Lexington and Concord. For a few weeks he was tried out at a recruiting camp, but his nearsightedness rendered him helpless without the aid of strong corrective glasses, and he was therefore soon dismissed as not fit for service. This was a severe disappointment to the ardent patriot and the sincere hater of slavery; but he turned to astronomy for consolation. He was with Dr. Gould from 1860 to 1864. The experience thus obtained was doubtless the incentive which took him to Russia, where he remained two years, 1865-1866, as a guest at the Nicholas Central Observatory, Pulkova, near Petrograd.

Returning to the United States in 1867, he served as an aid in the U. S. Naval Observatory until called to Cincinnati as the Director of the Astronomical Observatory at that place. Throughout his career as an astronomer, Abbe never lost his interest in atmospheric phenomena, and indeed we find that the dominant note in his inaugural address as director of the Cincinnati Observatory on May 1, 1868, was the practical results which would flow to the public, as well as to the astronomer, from a system of telegraphic weather reports.

Abbe's career as an active astronomer ended shortly after his acceptance of a responsible position in that science. His career as an active meteorologist began with the successful movement to interest the local

Chamber of Commerce of Cincinnati in a system of telegraphic weather reports.

The story of the establishment of a modest private weather service by the Cincinnati Observatory, in co-operation with the Western Union Telegraph Company has often been told. We will not repeat it here.

Professor Abbe's own personal feelings in the matter is reflected in a letter addressed to his father in New York, which contains the following statement:

"I have started that which the country will not willingly let die."

Less than a year after the first bulletin of the Cincinnati Observatory was issued, the Federal Government, through a congressional resolution under date of February 9, 1870, authorized the creation of a Weather Service, and placed it under the immediate direction of the Signal Service, a part of the military establishment under the War Department, in which it remained until June 30, 1891. On that date the meteorological duties were transferred to a bureau to be known as the Weather Bureau, and the latter was placed in the Department of Agriculture.

Professor Abbe began his duties in the Signal Service on January 3, 1871, as a Professor of Meteorology and Senior Scientific Assistant to the Chief Signal officer. He was continuously on duty from that time until June 4, 1915, when he took a year's furlough. Returning from furlough and being still in ill health he resigned on August 3, 1916, after a little more than 45 years continuous service to the Federal Government.

When Professor Abbe entered the Signal Service in 1871 he was assigned to the preparation of the tri-daily synopsis, probabilities and facts, or what would now be termed the forecasts. As soon, however, as certain army officers attached to the Signal Service as assistants to the Chief Signal Officer, could be trained to the work by Professor Abbe, he was relieved from forecasting duty and was regularly occupied as the senior scientific advisor of the service. His duties, which at that time had not taken concrete form, were later defined and he was assigned to what was at first called the Study Room,—later the Study Division.

Here, for nearly a score of years, Abbe was engaged in the consideration of questions relative to the investigation of meteorological phenomena, standards of measurement, altitudes and tables of reduction of observations; and later there were added to his care, the preparation of a Bibliography of Meteorology (upon which he personally spent much time) and the investigation of thunderstorms and tornadoes. The active work upon the two subjects last named was delegated to others.

In 1886 the Study Division was reorganized and merged with several other divisions into a new division, known as the Review Division.

The new division was to have charge of the preparation of the manuscript of the Monthly Weather Review, the Monthly Meteorological Summary and Review, the International Charts and the tri-daily Meteorological Record. To Professor Abbe was specifically assigned the preparation of a popular "Treatise on Meteorology and Meteorological Instruments" and the completion of the Bibliography of Meteorology. It was the custom at this time for the Army officers and certain of the higher class of civilian employees, including Professor Abbe, to alternate in charge of the various meteorological divisions of the Washington office, including the preparation of the tri-daily probabilities. The Probability Officer, as he was called, also acted as editor of the Monthly Weather Review for the month during which he was responsible for the probabilities—the editorial work, of course, coming in the month after the probability work had been finished. Thus it happened that throughout the military regime there was no single person continuously responsible for the editorial work of the Monthly Weather Review. When the Bureau came under civilian control a Board of Editors was appointed to conduct the Review, but this board was dissolved in July, 1893 and immediately thereafter Professor Abbe was assigned to the editorship, beginning with the number for August, 1893.

Meantime he had been variously occupied, mostly in the Study Division but occasionally, as in 1888, he alternated with others on the forecast work. He also made the forecasts of June 1891, the last month of military control and, finally, he was the official forecaster for August, 1893, which latter period marks the completion of his services as a forecaster.

It was in the capacity of Editor of the Monthly Weather Review that Professor Abbe is best known, and it was in that capacity that he found his most congenial labor. For upward of a score of years he conducted that Journal with marked success, bringing it to its present high standing as the representative meteorological journal of the English-speaking people, through his strong individuality, sincerity of purpose, and high ideals.

In all these forty odd years, Professor Abbe, while carrying on his official duties, never lost an opportunity to urge in public and private the importance of the study in colleges and universities of the fundamental problems of meteorology and in the public schools of the simpler phases of the subject. Nor was he unmindful of the good that would accrue from the study of meteorology to many persons who could not have the advantage of any regular course of instructions. To these, his appeal was to form local clubs or societies for the purpose of investigating problems of local climatology; the relation of local climate to any special crop or other similar investigations.

If I were to indicate that characteristic of his life-work which has

impressed me most, I would unhesitatingly name as first his unbounded enthusiasm for meteorology and his abiding faith in its future. Clearly, therefore, his great work was inspiring in others a measure of that fervent hope for the future that he himself felt. His was not the enthusiasm of a dreamer; he realized full well that results could be obtained only through sustained effort and was himself careful to set an example of industry that might well be imitated by others.

Professor Abbe was modest in his demeanor, almost to a fault. His tastes were of the simplest character. The top of a packing box, to serve as a desk, a plain stool, and a bottle of ink, easily satisfied his demands for office equipment.

A list of the papers of Professor Abbe will doubtless appear elsewhere. The list is a long one and I very much doubt whether it is now possible to prepare a complete one. It was his habit in the later years of his life to undertake more than it was humanly possible for any man to accomplish and naturally, in the course of time he accumulated a very considerable quantity of notes and partially completed papers. A number of these uncompleted projects were very dear to his heart. Time will permit me to mention but two of them. (1) The contributions to dynamic meteorology or to climatology, submitted by eminent meteorologists for presentation at the International Meteorological Congress held in Chicago in August, 1893, which were intended to form Section IX—General and Theoretical Meteorology—and Section X—Thunderstorms—of the complete report of that Congress, failed of publication, largely because no provision had been made to defray the necessary expense. Professor Abbe, during the twenty odd years that have elapsed since the date of the Congress, has never ceased to urge the publication of those papers, and, indeed, during the last year of his active editorship of the Monthly Weather Review he began the publication of some of them in that journal.

Single-handed, Professor Abbe was unable to overcome the departmental inertia that stood in the way of the publication of these valuable contributions at the proper time. They are now of interest chiefly from a historical point of view.

The second project which he hoped to complete was a full discussion of the cloud observations made by him while a member of the U. S. Scientific Expedition to West Africa in 1889. It will be remembered that the U. S. S. S. Pensacola was used to transport the party to the west coast of Africa to observe the total eclipse of the sun on December 22, 1889. For this expedition, Professor Abbe devised a nephoscope to use on vessels at sea, so as to enable the navigator to observe the motions of the clouds as accurately as he observed the winds.

Professor Abbe was always cheerful, I might say, over sanguine as to the future of meteorology. Indeed, I can pay no higher tribute to his cheerfulness than to record the fact that the only note of sadness

that I ever heard him utter, in more than thirty years close association, was with reference to his inability to complete the discussion of the cloud observations before mentioned and other projects.

I first met Professor Abbe in 1884 when it was believed that he had ceased active work as a forecaster and had taken up the more congenial occupation of study and investigation. At that time he was assisted by Junior Professors Winslow Upton, H. A. Hazen and Frank Waldo, and Mr. George E. Curtis. Professor Waldo alone of this number survives.

In my first meeting with Professor Abbe I had difficulty in finding him. In those days storage facilities were inadequate and it was necessary to store in the working rooms much of the material upon which the investigative force was engaged. After dodging sundry boxes and temporary shelves I finally came to the corner in which he was located. I was instantly rewarded by the warmth of his greeting and the sympathetic response to my inquiries.

His remarkable memory, his comprehensive view, which embraced practically everything that had ever appeared on the horizon of meteorology, his powers of observation, together with his linguistic ability, made him a veritable storehouse of information. As we have before intimated, the cheerfulness with which his knowledge was imparted to others, was a striking characteristic of the man.

As the poet phrased it:

> "Of manners gentle, of affections mild:
> In wit a man, simplicity a child."

Even under the stresses that sometimes arose in the early days of the service and indeed in some of the later days, Professor Abbe never lost his poise; never "sulked in his tent." He had the ability, as one of his colleagues has expressed it, of "being able to bend without breaking and to straighten up when the blast was over." By reason of his rank as Senior Scientific Assistant he was the target for more than one ill-advised attempt to belittle scientific methods in the conduct of the work of the Weather Service. Fortunately these efforts came to naught.

It would be unfortunate to close this memoir without reference to Professor Abbe the man, as distinguished from Professor Abbe the Scientist. While his studious habits afforded little time for relaxation, yet on occasions, rare it is true, he was able to relax as completely as anyone I ever knew. Two special occurrences come to mind. At the Weather Bureau convention held in Milwaukee, Wis., in August, 1901, on which meeting Professor Abbe was in attendance, the delegates, after a rather strenuous session, were taken on a sight-seeing trip around the city, finally fetching up at the Press Club where there was the usual good cheer and general abandonment of the formality

which had characterized the official meetings. No one who attended the Press Club gathering will soon forget the brief session of social relaxation and especially the "hit" of the occasion which was staged by "Old Probs" who, mounted upon a convenient table as a vantage point, gave an ocular demonstration of the manner in which German University students consume that for which Milwaukee is famous. Needless to say, so unique an occasion formed an indelible impression upon the memories of his audience. It was characteristic of the man, even in moments of relaxation, that he was able to bring up memories of some previous event that were germane to the moment.

While at the Mount Weather Observatory it was my good fortune to have Professor Abbe and his wife as members of the official family. I shall not soon forget on occasions when extraordinary snowstorms made locomotion somewhat difficult, the picture of Professor Abbe on his way to the Mess-Hall, dressed in a great fur coat and high boots, floundering and rolling in the deep snow, with the zest of a ten-year-old boy.

Many honors came to Professor Abbe during his active career. Perhaps the two which he most prized were the Symons Memorial Gold Medal, bestowed by the Royal Meteorological Society of Great Britain in 1912, and the Marcellus Hartley Medal, awarded on April 18, 1916, by the National Academy of Sciences of the United States.

The Council of the former society, in awarding the medal, said in part:

"Professor Abbe was one of the first to realize the importance of experimental investigations of atmospheric radiation and it was largely due to his enterprise that the well-known researches of Hutchins and Pearson were undertaken. The importance of this work has been recently emphasized by its application to the explanation of the isothermal conditions of the upper atmosphere. Professor Abbe has contributed, therefore, to instrumental, statistical, dynamical and thermo-dynamical meteorology, and forecasting. He has, moreover, played throughout, the part not only of an active contributor, but also of a leader who drew others into the battle and pointed out the paths along which attacks might be most successful."

The award of the Marcellus Hartley Medal, "for eminence in the application of science to public welfare," coming from an association of which he had long been a member, was to him an honor beyond price. His death occurred just about six months after the presentation of the medal and thus passed from us a loyal son of science, an enthusiast who led the way, set a high standard of achievement, rejoiced in the good work of others and was always a friend to man.

MEMOIR OF HENRY GANNETT

N. H. DARTON

Henry Gannett was born at Bath, Maine, August 24, 1846. He attended local schools until his twentieth year, when he went to Harvard College. Here he graduated, receiving his baccalaureate in science from the Lawrence Scientific School in 1869, and the next year the degree of mining engineer at the Hooper Mining School. He continued work at the Harvard Astronomical Observatory from 1870 to 1871, and in 1871 went to Spain with Professor Pickering to observe the eclipse of the sun. In 1899 Bowdoin College gave him the degree of LL. D. He was diverted from astronomy by an invitation to join the Hayden Survey and until his death continued with this survey and its successor, the U. S. Geological Survey, except for temporary assignments to other bureaus for census work. In 1874 Henry Gannett married Mary E. Chase of Waterville, Maine, who with two daughters and a son survives him. After an illness of several months, through which his associates gathered around him in devoted comradeship, Gannett died on November 5, 1914.

Gannett was one of the founders of the Association of American Geographers and took an active part in several of the earlier meetings. He was dear to many of our members as an intimate friend, who had worked in close harmony with them through the many years of his energetic life, and he was universally known for his geographic productions. Early in 1883 he helped to found the National Geographic Society. He was chairman of the Research Committee of this society until his death, and took an active part in organizing the expeditions to Mount Pelee and La Soufriere, the Polar Seas, Alaska and Peru. He held several offices in the National Geographic Society, and was its president from 1910 until his death. In this position he won the loyal and loving esteem of his co-workers.[1]

Gannett very early in his career realized the importance of geography as a basis for many sister sciences and his most zealous efforts were directed to disseminating geographic knowledge and fostering an appreciation of it in the popular mind. In fact, the presentation of facts for popular utilization was the principal purpose of Gannett's work. In his maps, in his forestry studies, in his conservation investigations, and in his census reports, he endeavored painstakingly to present facts in such a way that the public could assimilate them to advantage.

As a map producer Gannett well deserved the title "father of

[1] See Memorial of Henry Gannett, S. D. N. North, National Geographic Society, Washington, D. C., 1915.

American map making," which was often applied to him. In 1871, at the age of twenty-one, he joined the Hayden Survey and began a career in topographic mapping which is unique in many respects. Most of the work was in the western wilderness, at that time unexplored and savage, and he rapidly produced excellent reconnaissance maps of wide areas. These were intended to serve as a basis for the geological investigations which closely followed and in some cases were contemporaneous. He had the intrepid spirit of the explorer and at the same time the genius of the map-maker. When the conditions in the field and the requirements are considered, his results were remarkable. Every trip that Gannett made in the eight years of his early exploratory work, resulted not alone in maps but in the collection of geographical data of various kinds which were useful to him in later work.

In the same way Gannett's work as chief geographer of the U. S. Geological Survey tended always to the exposition of facts that could be utilized for other scientific investigations, especially the geological reconnaissances of the early stages of the Survey. During the fifteen years of Gannett's service as chief geographer of the U. S. Geological Survey, most of its methods of map-making were developed under his direction. His energy, originality and ability to inspire intelligent work were factors that had an important bearing on the output of the topographic branch. His "Manual of Topographic Surveying" was a very useful exposition of the Survey's methods and was in such demand that it was republished as a Bulletin (No. 307).

Gannett was an indefatigable compiler of geographic materials, bringing together data for the contour and other general maps of the whole United States, and for many special maps of various kinds, such as those showing magnetic declination, and rainfall. He supervised the preparation of gazeteers of several states and of Cuba, a review of data on boundaries and areas of our states and territories (Bulls. 226, 302), an account of the origin of place names in the United States (Bull. 258), an analysis of river profiles (Water Supply Paper 44), and a discussion of the mean altitudes of the United States.

As in topography, so also in forestry, Gannett's work was largely of a pioneer character. It antedated the conservation movement by a decade, and the statistics he had gathered in that time were found immediately available for the use of the Bureau of Forestry on its organization. His special talents were appreciated when the National Conservation Commission was appointed and Gannett served as its geographer and editor from 1903 to 1909. The reports of this Commission are an example of Gannett's vast energy in the search for facts, his cleverness in correlating them and his prophetic realization of their value in the future development of our country.

In the census work which Gannet first undertook in 1880 there was

a wide and virgin field for his great ability for orderly organization. He was geographer of the Tenth, Eleventh and Twelfth censuses, and assistant director of the censuses of the Philippine Islands in 1903 and of Cuba in 1907. The results of this insular work were published in several interesting volumes, setting forth not only the purely statistical results, but giving also many valuable facts concerning the resources and possibilities for development of the islands.

Gannett's published contributions to physiography or geomorphy were not numerous, but he made many valuable suggestions to his associates. He was one of the first to recognize hanging valleys and to point out their significance. His most notable publications in this line were the two physiographic folios issued by the U. S. Geological Survey in 1898 and 1900. Each consisted of ten typical maps selected from the Survey sheets, with text prepared by Gannett.

In many of the Hayden reports and annual reports of the U. S. Geological Survey are articles by Gannett, covering a surprisingly large field of investigation. Besides these generous contributions were professional papers, principally on forest conditions, and bulletins on various subjects. In addition to articles in encyclopedias and in other works of reference, including Baedecker's Guide to the United States, Gannett wrote for outside publication his "Building of a Nation" (1895), and his "Commercial Geography" (1895), the latter in collaboration with Garrison and Houston, and a volume on the "United States" in Stanford's Compendium of Geography in 1898.

One of Gannett's most important services to geography was the organization of the Board of Geographic Names, which, beginning as an informal association with Gannett as a moving spirit, has become a permanent body in the federal service. This Board consists of representatives of several federal bureaus appointed by the President; its function is to consider geographic names used officially. Gannett was chairman of this Board from 1894 and guided its work with great success.

Gannett was secretary of the Eighth Geographical Congress, held in the United States in 1904. He was a founder of the Geological Society of America; a corresponding member of the Royal Geographical Society of London, of the Scottish Geographical Society and of the Geographical Society of Paris. He was a member of the American Geographical Society and for many years associate editor of its Bulletin. He was also a member of the American Statistical Society, the American Economic Association, the National Geographic Society, and of the Washington Academy of Sciences.

In the death of Henry Gannett American Science has lost one of the pioneers who had an important share in the development of geography in this country into an organized science.

TITLES AND ABSTRACTS OF PAPERS

New York, 1916

Presidential Address—Mark Jefferson.

Geographic Provinces of the United States. See page 3.

William Bowie.

The Gravimetric Survey of the United States.

The gravimetric survey of the United States may be considered to have been begun in 1890, when the Mendenhall one-half second invariable pendulums were first used. Previous to that date, 13 stations had been established in the United States, but the pendulums used in connection with them did not give very accurate results, as the later work showed.

With the invar pendulums the probable error of a station in the United States, referred to the Potsdam system, is, on an average, about ± 0.002 dyne. This is about one part in one-half million.

In December, 1908, there were 47 stations in the United States, established by means of the Mendenhall pendulums; while in December, 1916, there were 259 stations in this country.

The pendulum data are of value, first, in the determination of the flattening of the earth and the terms in the gravity formula. Second, they give the value of the intensity of gravity which is needed in physical and chemical laboratories. Third, they are used in researches into the subject of isostasy.

It was this latter use of gravity data which was considered at length in the paper, and the results of the most recent investigations into the subject of isostasy by the author were given.

His value for the depth of compensation as derived from gravity observations alone was 95 kilometers. The value for the depth of compensation derived by Hayford, from previous investigations, from data in mountain stations, was 97 kilometers. The author believed that the means of these two values is the best depth of compensation from all gravity data.

The flattening of the earth, derived from 358 gravity stations distributed in a number of countries, is 1/297.4. This value agrees very well with those previously determined which have been considered strong.

The author stated that a rather decided relation was found between gravity anomalies and coast topography but that there was no apparent relation between the anomalies and any other class of topography.

Some decided relations were found between the gravity anomalies

and certain geological formations, especially the Pre-Cambrian and the Cenozoic.

He stated that further work on the gravimetric survey of the United States will be done by the Coast and Geodetic Survey and he expects that it will lead to important discoveries regarding the distribution of densities in the outer portions of the earth, especially within the outer ten miles.

Charles F. Brooks (Introduced).

New England Snowfall.

New England is famous for its northeast snowstorms. These great storms, however, are not widespread, for New England, though small, has very different conditions of exposure to the snow-bearing winds. The highlands are the snowiest because they are cold, moist and windy. Particularly snowy are those slopes which are openly exposed to easterly or northeasterly winds, or in the north, to the westerly winds from the Great Lakes. The intermontane valleys have less snowfall because of the higher temperature, smaller precipitation and less exposure. In the coastal region, since the other conditions are favorable, the snowfall depends on the temperatures. As a result, the snowfall of the second half of the winter is the greater; and also the coast may be said to exceed the inland snowfall then, if due allowances are made for topography. New England, as the focus of most of the cyclones which cross the United States or come up the east coast, has all parts traversed by numerous centers. The strongest cyclones pass New England on the south or cross through the southeast; so this section from time to time has a characteristic "old-fashioned snowstorm."

Godfrey L. Cabot (Introduced).

Maps for Use by Aviators.

Collier Cobb.

Colonial Transportation in North Carolina.

W. S. Cooper (Introduced).

Plant Succession after Glacial Recession in Alaska.

Studies were made during August and September, 1916, of the establishment of vegetation after glacial recession in several localities in southeastern Alaska. Glacier Bay was found to be especially favorable for such study, because of the extremely rapid recession which has taken place during the last century and a quarter, and because the positions of several of the ice fronts have been accurately located several times during recent years. The stages in the vegeta-

tional succession were worked out in detail, and the time factor was studied by age counts of woody plants. Permanent quadrats were located at the ice limits of known date, for the determination of successional progress in a known period of years, and for future study. The present paper is not a record of finished research, but an announcement of work in progress, given with the hope of co-operation from any one who may visit the region in future years. The quadrats are so located that they may easily be found, and charts or at least photographs of them made at future times will be of great value.

Sumner W. Cushing.

Shīharikota and the Yānādis. See page 17.

W. M. Davis.

The Sea Cliffs and Coral Reefs of Tahiti.

Tahiti, the largest of the Society Islands, is a volcanic doublet, submaturely dissected by radial consequent valleys, the larger cone being 17 nautical miles in diameter, and 7,381 feet in height; the smaller one, southeast of the other, 8 miles, and 4,341 feet; a low isthmus, but little more than a mile across, connects the two. As Dana long ago noted, the central parts of the cones are destroyed, and there the narrow inter-valley ridges are sharply serrate; but in the peripheral slopes, where the radial consequent valleys are farther apart and less deep, the ridges descend in slanting spurs, topped by sloping triangular sectors which represent the initial slope of the cone, little worn. Dana and nearly all later observers failed to mention the mature sea cliffs in which the radial spurs terminate; but they are well described by Agassiz (1903) as rising in some instances more than 1,000 feet above sea level along the windward eastern coast, and as sometimes undercutting small valleys from which the streams fall in cascades. The cliffs are not vertical, but dip at angles of 40°, 50° or 60°.

The larger valleys descend below present sea level, for some of them are entered by arms of the sea, and all the others are occupied near their mouths by triangular delta plains, which commonly extend beyond the line of sea cliffs and unite in a confluent alluvial strand plain, on which almost the entire population live. The valley ends being submerged, the cliff base line and the abraded platform that must extend in front of the cliffs must also be submerged. That such is the case is indicated by depths of over 20 fathoms close along shore, while off the cliff coast of Normandy, where the sea is still cutting at the cliff base, a depth of only 10 fathoms is not found for one or two miles off shore.

The discontinuous barrier reef by which both cones are surrounded

encloses a lagoon from half a mile to a mile or more in breadth, and from 15 to 30 fathoms in depth. Contrary to the belief of Murray and of Agassiz, the better enclosed parts of the lagoon appear to be filling up by inwash of calcareous detritus from the reef and by outwash of volcanic detritus from the island. The reefs could not have been present while the cliffs were cut back; and some change must have occurred to alter the reef-free, cliff-cutting conditions then obtaining into the reef-building conditions now obtaining. This change appears to have been the submergence by which the abraded platform and the valley mouths were drowned. Previous to the submergence Tahiti must have resembled the volcanic island of Reunion in the western Indian Ocean, where cliffs now rise from a wave-swept beach of volcanic detritus, which presumably lies on an abraded platform and which inhibits reef growth because its cobbles and gravels are frequently shifted by the waves. If submergence should occur there, the detritus from the valleys would be pocketed in the valley embayments, the abraded platform would be swept comparatively clean, and reefs might then grow up from the platform, as they are now growing up from the submerged platform around Tahiti.

The bearing of these facts and inferences on several theories of coral reefs was discussed. All the theories which postulate a fixed relation between the reef foundations and the surface of the ocean are excluded by the evidence of submergence, given above. As the depth of submergence, determined by prolonging downward with decreasing declivity the side slopes of some of the delta-filled valleys, is 500 or 600 feet, neither a rise of the ocean due to an uplift of its bottom elsewhere, nor the rise of the ocean at the close of the Glacial Period can be accepted as the whole cause of submergence; the remaining cause must be sought in the subsidence of Tahiti itself, and thus Darwin's theory of intermittent subsidence is supported.

The relation between the narrow, steep-sided valleys of Tahiti and its high, mature sea cliffs has an additional and important bearing on the Glacial-control theory, as follows: This theory assumes that, when the ocean was chilled and lowered (33 to 38 fathoms) during the Glacial period, the corals of most reefs were killed, and the dead reefs were then abraded by the waves; it also assumes that the embayed valleys, by which the central islands of barrier reefs are characterized, were eroded while the Glacial ocean was lowered and were drowned when the Postglacial ocean rose to its present level; and it explains the absence of cliffs on the spur ends between the embayed valleys of such islands by the resistance of the lavas of which the spurs are composed. Tahiti shows that this explanation is not correct; for the same period which sufficed for the immature erosion of the narrow Tahitian valleys sufficed also for the mature erosion of the Great Tahitian cliffs; hence in other islands, where the embayed valleys

are as a rule more mature than those of Tahiti, the spur ends should now be more strongly cliffed, if the encircling reef had been killed and abraded during the Glacial period. But except for little bluffs, 10 to 50 feet in height, fronted by shallow rock platforms and therefore the work of the lagoon waves at present sea level, the spur ends of other islands are not cliffed, and therefore their reefs were not killed and abraded; and thus certain essential elements of the Glacial-control theory are discredited. Appeal should not be made to a supposed superior resistance of the rocks in the non-cliffed islands, for which there is no warrant; for if their rocks are more resistant than those of Tahiti, then the erosion of their mature valleys must have been very slowly accomplished; and if the erosion period of only narrow valleys in the supposedly weaker rocks of Tahiti was sufficient for the abrasion of great sea cliffs, then the erosion period of wider valleys in the supposedly harder rocks of the other islands should have been sufficient for the abrasion of still greater cliffs, provided the encircling reefs were at that time dead. But as these greater cliffs are not found, the reefs cannot have been killed; hence the supposition of superior resistance in the rocks of the non-cliffed islands is not only unwarranted, but unavailing. Tahiti thus indirectly gives strong support to Darwin's theory of upgrowing reefs during intermittent subsidence.

J. W. Goldthwait.

A New Model of the Mt. Washington Range in New Hampshire. —Read by Title.

The model, which is here exhibited for the first time, is based on "A map of the Mt. Washington Range," published by the Appalachian Mountain Club in 1914. It is about six feet by four, and includes not only this central range of the White Mountains, but the adjoining valley of the Saco at Crawford Notch, Bartlett and Jackson, the Ammonoosuc valley at Bretton Woods and Fabyans, the Androscoggin valley at Gorham, and "the Glen." The scale, both vertical and horizontal, is three inches to the mile. The absence of vertical distortion affords a realistic view of the mountain slopes, in which attention is particularly called to the somewhat peaked, though glaciated summits, the extensive graded "lawns" or "alpine pastures" and the cirques carved in the flanks of the range by mountain glaciers.

J. Paul Goode.

A New Idea for a World Map: A Substitute for Mercator's Projection.

There is a growing protest among teachers and students against the use of Mercator's or other cylindrical projection, showing the earth's surface as a unit, because of the progressive distortions of area with

increase of latitude. It is realized that the continual use of Mercator's projection fixes in the mind of the observer very erroneous impressions of the relative sizes of areas, and that these bad impressions persist, in spite of every caution and every effort to fix true relations by study of other projections.

The contribution here presented is a method of interruption of Mollweide's homalographic projection, such that each continent in turn is given the great advantage of a place in the middle of the grill, where the maximum truth of form is guaranteed. The homalographic projection is an equal area projection, thus continents and other unit areas may be compared with each other in their true size. Also this projection, in common with Mercator's projection, offers the very great advantage of having latitudes represented by right lines, trending with the equator, facilitating the study of comparative latitudes. The homalographic projection also shows the earth's surface *entire*, a thing the Mercator's projection can not do. For all these reasons the interrupted homalographic projection as here presented, offers the maximum of teaching advantages for all study of world distributions.

Roland M. Harper.

The Forests of the Eastern United States: Their Past, Present, and Future.

About seven-eighths of the territory of the United States east of the Great Plains was originally covered with forests, of great diversity, including such types as the spruce forests of the extreme north, the hardwoods of the Ohio valley, the long-leaf pine of the southeastern coastal plain, and the tropical hammocks of southern Florida.

In the last 200 years or so, the forest area has been reduced about 40% and the total stand of lumber about 60%. The early exhaustion of the forests has often been predicted, but such predictions have nearly always turned out to be exaggerated. The influences tending to preserve the trees seem at present to be nearly equal to the destructive influences, and our forests promise to be an important source of wealth for many years to come.

Alfred J. Henry.

Flood Producing Rains in the United States, 1916.

The rainfall of 1916 in the United States was characterized to a considerable extent by the occurrence of heavy rains in pairs, the first storm being almost immediately followed by a second equally severe storm that swept over a nearly identical path and thus there was naturally an extraordinary concentration of rainfall over restricted

areas. Such concentration was especially noted in southern California and Arizona and again in eastern Oklahoma, Arkansas, Missouri, southeastern Kansas, Illinois and Indiana, in the latter part of January.

In July two tropical cyclones passed inland, over the East Gulf and South Atlantic States, the first in the vicinity of Mobile, Ala., and the second near Charleston, S. C. The intensity of the rainfall attending these storms was in many cases extraordinary and the concentration of rainfall over rather wide areas resulted in severe general floods which in some localities were unpredecented.

The loss of life in the January and July floods was about 130 and the property loss for the entire year about 36 millions.

R. S. Holway.

The Marine Terraces of California and Related Problems.

George D. Hubbard.

Possible Local Glaciation in Southern Vermont.

The communication was a preliminary report only and contained a brief description of the moraines, eskers and kames found during the summer of 1916 in the vicinity of Wilmington, Vermont. These features are very abundant and have not been disturbed by ice since they were made. They seem to indicate a large development of valley dependencies on the margin of the waning Wisconsin ice sheet, or local valley glaciers after the withdrawal of the continental glacier. The latter explanation is believed to be supported by the following evidence: 1. The valleys in which these features lie are closed in on the west by the Haystack-Pisgah range and on the north by another high range, cols of which show no signs of having been spillways for glaciers. 2. The moraines, looped across the valleys, are arranged with reference to the heads of the local mountain valleys, heads pushed against the peaks instead of the cols. 3. One valley head has a well formed cirque occupied by a lake in a rock basin. Fresh moraines loop across this valley at many points entirely up to the lake. A detailed field map was shown.

Ellsworth Huntington.

Fluctuations of Our Southwestern Lakes.

A study of a series of basins at the eastern base of the Sierra Nevada in 1914 confirms the conclusion that there have been marked variations of climate during the past few thousand years. In some cases old strands have been covered by alluvial fans during a dry period when the lakes fell to a low level. Upon these four other abandoned strands are now visible, showing that the water rose once more almost

to the previous level. This indicates not only a general fall in the level of the lakes, but a series of oscillations first one way and then the other, with a general tendency toward aridity. At Owen Lake Gale's study of the salts dissolved in the lake and in the river which feeds it, indicate that the period since the last overflow can scarcely be more than 2,500 years. This makes it possible to correlate the strands with the fluctuations in the growth of the big trees on the opposite flank of the Sierras. The harmony between the cycles indicated by the strands and by the trees is close. Other lakes such as Mono and Pyramid show similar indications of fluctuating climate.

In studying the cause of such fluctuations the first step seems to be to ascertain exactly what sort of changes are in operation at the present time. At Lake Mono, for example, there has been a recent rise of level. In 1914 the water stood higher than at any other time for at least 130 years. This is indicated by the rings of certain trees which have recently been killed by the rising of the salt water. It is interesting to note that within a comparatively few years many old trees have been killed by an opposite cause in India and South Africa. In both of these cases extreme drought occurred upon the equatorial side of the subtropical belt, whereas the California lakes lie upon the polar side of that belt. This seems to indicate a cyclical shifting of zones which is even now in progress. It produces marked effects in certain border regions, but is comparatively unimportant in the central portions of the zones. The shifting seems to take place in harmony with variations in solar activity and in the consequent paths of storms.

W. L. G. Joerg.

Relief Models as a Source of Information for the Geography of the United States.

The paper dealt chiefly with the utilization of existing relief models of states and other portions of the United States for the representation of generalized relief on maps. The contour method, although admirably suited to detailed maps such as to the topographic sheets of the U. S. Geological Survey, does not lend itself well to general maps. On these relief is best represented in a plastic manner, as by shading or hachuring. As this method is not as highly developed with us as it is abroad, we have resorted to modeling. The paper suggested using photographs of the numerous existing models of scientific worth either directly as relief bases for maps of their respective areas, to be reproduced, for example, in half-tone, or indirectly, as a guide for a shaded drawing. A survey of these models, which cover, as far as it had been possible to ascertain, 22 states or about one-third of the total area of the country, was given, illustrated by lantern slides of the majority of them. An additional value which attaches to these models is due

to the fact that many of them cover regions for which no topographic sheets exist or the topography of which is otherwise not readily available.

Lawrence Martin.

Gravel Terraces of the Mississippi River in Wisconsin—Read by Title.

The terraces of the Upper Mississippi in Wisconsin and across the river in Minnesota and Iowa are distributed through a distance of 213 miles directly, or 260 miles as the stream flows. The river has a terrace on one side or the other for 126 miles of this distance—the length of all terraces, including those that overlap and also parallel terraces in steps being 200 miles. The largest terrace is 15 miles long, 3 miles wide, with an 80-foot scarp facing the river. One terrace in the middle of the valley is 9 1/3 miles long, 3/4 of a mile wide, and stands 30 feet above encircling floodplain deposits. The terraces are made up of outwash sand and gravel of Wisconsin age. They lie in the bottom of a preglacial gorge or trench, bordered by precipitous bluffs 230 to 650 feet high. The rock floor of the gorge lies 150 to 210 feet below the present river level; the higher terraces rise more than 100 feet above the river; hence the gorge is really 750 to 800 feet deep in places and the terrace gravel is 200 or 300 feet thick. The Mississippi floodplain in Wisconsin is nearly everywhere swampy; accordingly the terraces supply practically all the improved farm land and the sites of all the river cities and villages, including La Crosse and Prairie du Chien, Wis., Winona and Red Wing, Minn., Dubuque, Iowa, and many others.

The terraces fall in two groups: (a) few small and low terraces south of La Crosse; (b) numerous, large and high as well as low terraces to the north. There are usually two low terraces—20 feet and 40 feet above the river. North of La Crosse, where there are terraces for 87% of the distance, the low terraces are usually present and there are higher terraces, entirely absent to the south, four or more in places stepping up the 105 feet or higher above present river level.

The explanation of this increase in number and height of terraces seems to be that, as in the case of beaches of the Glacial Great Lakes, (a) the terraces remain parallel downstream from the southernmost of the hinge lines, (b) they increase in number and in altitude to the north of this line, which appears to cross the Mississippi in the neighborhood of La Crosse close to or a trifle farther south than where Taylor (conjecturally) places the Whittlesey hinge line. The uplift of the land toward the end of the Glacial Period is thus seen to have had the normal effect on rivers, the terraces in the tributaries of the Upper Mississippi appearing to respond to the same control.

Emmanuel De Martonne (Introduced).

The Physiography of the Carpathian Mountains.

A. E. Parkins (Introduced).

The Development of Manufactures at Detroit.

Although Detroit was founded in 1701, it was not until the early part of the nineteenth century that the real development of manufacturing began. For nearly 150 years commerce was the dominant interest of the settlement.

In 1810 the total value of manufactures was $24,742, in 1909 the value was $223,000,000. This wonderful growth is for the most part only a normal growth, characteristic of several cities of the Interior, and is chiefly the result of the westward migration of people, resulting in an increasing density of population, and a westward migration of manufactures. Fundamental to the normal growth lie the wonderful improvements in transportation that characterize the last century.

Among the broader geographic factors operative at Detroit are those associated with its position. It is situated on the largest and most important series of waterways in the world and near the entrances to the "Gateways" through the Appalachian Barrier. Since the beginning of the railroad era its position on one of the great trunk lines of the country is of vital importance, particularly since the Detroit River here occasions a break in land transportation only partially overcome by car, ferry and tunnel (the latter since 1910). The city is within easy reach of the copper and iron ore deposits of the Lake Superior Region and the coal of the Appalachian fields. It is on the border of the most productive agricultural region of the United States, and for many decades had access to large forests of commercial timber. Being the oldest settlement on the lakes, for a long time it enjoyed almost a monopoly of the benefits arising from these important factors.

Roderick Peattie (Introduced).

The Geography of the Lower St. Lawrence Valley.

The Lower St. Lawrence Valley includes the valley slopes from Quebec to the Gulf. The north shore, except for a few fertile wedges, has a broken settlement with a meager economy. The south is densely populated, excellent farms running ten to twenty miles back over the gentle uplands. On both shores the commerce is chiefly in wood products, cheese, butter and live stock. For the most part the settlements, especially to the north, are economically independent. In this well-defined, isolated unit-area still prevails an ancient economy, language, philosophy, folk-lore and architecture, crystallized to an extraor-

dinary degree and creating a significant provincialism. This study is the result of a library investigation followed by field work in the last season.

William Gardener Reed.
Plimsoll's Mark.

The classing of vessels according to seaworthiness has been practiced in England for nearly 200 years. It has been recognized that the conditions on different oceans and at different seasons are not the same. Insurance by distributing the risk also made it more possible to send vessels to sea in bad weather. In the sixties overloading appears to have been common, and Samuel Plimsoll began his efforts which resulted in the adoption of a load-line mark by 1876. It was not until 1894, however, that the position of the mark was fixed by government authorities. In 1899 the Board of Trade determined different load-lines for fresh water, for "Indian Summer," for summer, for winter and for "North Atlantic Winter." Since then Germany and Denmark have adopted "Plimsoll's Mark." The adoption and use of this mark emphasizes the influence of geographic conditions on commerce.

Lawrence V. Roth (Introduced).
Geographic and Historic Factors in the Growth of Certain American Cities.

The movement of population towards the larger cities in the United States falls into four periods, each introducing a new geographic area. The first period begins with our Colonial history and the development of cities takes place along the Atlantic Coastal Plain; during the second era, beginning about 1810, city growth is most notable in the Mississippi valley along the river fronts; beginning about 1850, a third era opens and the cities of the Great Lakes district have a notable growth; during the fourth period, opening about 1900, a relatively sudden movement of population is found on the Pacific coast. Significant geographic and historic factors were read into this movement of population as shown graphically on a large chart.

H. L. Shantz and Raphael Zon.
A New Classification of the Native Vegetation of the United States into Natural Groups.

The vegetation of the United States was divided into plant formations defined as the largest vegetation units which could be distinguished by comparative uniformity of physiognomy, of botanical composition, of climatic and environmental conditions, and by con-

vergent development. On this basis the distribution of two grass formations, three desert shrub formations, nine forest formations, and five minor communities was mapped.

Eugene Wesley Shaw.

Notes on Man and Nature in Tamaulipas and Vera Cruz, Mexico. —Read by Title.

1. *Relations of pre-Columbian aborigines to environment.*

Indians.—Various bloods and natures but generally religious, superstitious and social. Surface.—Plains with irregularly scattered commonly conical mountain peaks and occasional ranges up to 4,000 or 5,000 ft. in height, some of which are not shown on current maps. Temperature.—Average probably low for tropics, cold often penetrating; blanket needed nightly, hence part of costume. Soil.—Calcareous and fertile. Precipitation.—Rather low, increasing southward. Vegetation.—Forest a thorny thicket rather than tropical jungle, almost uninterrupted. Wild animals.—Natural supplies of wild meat fairly good,—deer, large and small birds, sea and river fish, shrimp, etc. Snakes and mosquitoes much less troublesome than wood ticks and other insects.

2. *Changes in customs and relationships due to 16-19th century events.*

Perhaps because of oppression of large part of population, many aboriginal customs have been retailed with slight modification. Mingling of bloods general, but apparently one-fourth of the population are pure Indian. Most of them have been more or less enslaved, some driven into the mountains. Diet.—Corn, as before, the main article, ground by hand just before being made into tortillas (unleavened cakes); black beans, meat, peppers, tomatoes (type locality—Aztec tomatl), sugar, coffee, bananas, etc.; chile and tamales not omnipresent. Dwellings.—"Bamboo cages" thatched with palm leaves or straw and often chinked with mud; adobe rare. Doors and windows scarce. Religion.—Mostly Roman Catholic, some pagan; curious mixtures common. Transportation.—Some by railways and wagons, but mostly on backs of burros or men. Surprising lack of wagon roads, even where surface is smoothest. Amusements.—Drinking, dancing and gambling, including lottery on enormous scale. Bull and cock fights rare. Village life popular. Morals.—Comparatively low, but ideals not altogether wanting, and faithfulness of servants often surprising. Cleanliness.—Rivers and water holes frequented resorts for laundering and bathing. Education.—Most of population seem able to read and write Spanish but display little desire to learn English, which is surprising in cab drivers and porters.

3. *20th century changes in relationships and customs,*—due largely to discovery of petroleum and to revolutions. Wealth.—Increased for small

part of population,—oil field land owners and laborers. Psychologic equilibrium, law, deportment, industries and currency demoralized by revolutions. Differentiation increased between more bellicose and rapacious elements and more peace loving and timid. Failure of Madero's plan to redistribute land has led warlike Indians to kill or drive off many landowners. Outrages common and of many sorts, but usually with considerable show of politeness, and apparently like battle casualties, more likely to end in death than crippling. Cultivated area greatly reduced and grown up in thickets. Comparisons with ranch and mining camp wild west of United States interesting. Armed marauders are soldiers, a tattered and very poorly equipped lot, whose principal motive seems to be gain. Other men do not carry weapons openly, but often concealed knives. The almost unpenetrable thicket and the mountain fastnesses are the retreats of the timid and persecuted folk rather than the home of the robbers, for most if not all bandits seem to have joined one or another of the national factions. Natural barriers of comparatively slight importance in revolutions.

O. D. von Engeln.

Glacial Erosion of Rock Basins—With Especial Reference to the Conditions Applying in the Finger Lake Region of Central New York.—Read by Title.

The finger lakes of Central New York, of the Lake District of England and of the Italian-Swiss Lakes on the south slope of the Alp; and the fiords of Alaska, Patagonia, Norway, New Zealand and some of the Scottish lochs are all similar in outline and form of hollow. If carved by ice the basin feature of all of them is the result of concentration of the ice erosion action at particular parts of linear valleys earlier developed by streams. With the single notable exception, however, of the Central New York Finger Lakes the other basins of this nature occur where the ice movement was down valley. In consequence of this, conspicuous morainic barriers are usually present at the lower ends of these "down-valley-movement" basins, and such moraines are an expectable feature there, because the situation would normally mark the end of a pronounced ice tongue. The high wall-moraines of the Italian Lakes are especially typical examples. Such barriers no doubt account for a considerable part of the depth of the "down-valley-movement" basins.

In the case of the New York Finger Lakes, on the other hand, the ice movement was upstream—unless the preglacial drainage is interpreted to have been southward and eastward from points considerably to the north of the present divide. Even in this case the mass of the continental ice front must, in this region, have impinged on a rock escarpment of considerable height, extending east and west at right

angles to its movement. On the north front of this escarpment, in line with the direction of ice movement and apparently widening normally as they extended toward the ice front, were a number of parallel, preglacial valleys. Some of these may have had a south slope, others almost certainly sloped to the north. These valleys obviously afforded the readiest paths for the further progress southward of the oncoming ice masses and into them were thrust advanced lobes, while the main body of the ice was dammed back for the time being by the escarpment front. This dam may be reckoned of about 1,000 feet altitude. It created a "head" of ice, a reservoir from which ice poured into the north-south valleys. If the valleys sloped to the north, they must have narrowed toward their heads in the south, and this constriction offered a progressively increased resistance to the further advance of the ice. But once the ice was trapped, so to speak, in the V opening of the north end of the valleys, it could not escape these guiding lines, and crowded by the head of ice behind, its erosive effects were concentrated on the more constricted parts, as is indicated by the fact that the basins are deepest where the valley is narrowest. Later when the ice grew in thickness sufficiently to overtop the divide region completely, these valleys continued to be the channels through which the deepest and presumably the most rapidly flowing ice moved. As a result the divides were notched along these lines and through valleys were created.

If this proposal, that the Central New York Finger Lake basins are of unique development in that they are the result of ice thrust into valleys sloping against the direction of ice advance, is unacceptable, then the only alternative is to correlate them with the other finger lake and fiord occurrences,—in other words, ascribe them to the result of ice erosion as a concomitant of "down-valley-movement" and concentration.

In this case also the flow would originate in an "ice-head" back of the escarpment slope. The scour would further tend to be concentrated where the source volume and downslope acceleration conjointly made themselves most effective. In the wider parts of the valleys beyond the divide ridge there would occur broader distribution of uniform rate of flow, decreased velocity because of decreased slope; and, during the waning, lobate phases, pronounced accentuation in thickness of deposit, as valley-fill terminal to the lobes.

This valley-fill would then constitute a main part of the barrier creating a lake basin. If a rock basin constituted part of the depression its development would be on a much smaller scale than in the other case. The fact that near surface rock barriers cut off at least part of the width of the valleys to the north, while borings up to 1,000 and more feet in depth fail to disclose rock in the drift filling of the valleys to the south lends support to the south slope interpretation.

In this may be found a suggestion also for a partial reconstruction of the preglacial drainage of New York State.

Robert DeC. Ward.

Rainfall Types of the United States.

A revision of the rainfall types of the United States. Fourteen types were distinguished and each one was illustrated by a composite curve of the monthly rainfall amounts. A map was exhibited showing the geographical distribution of these types.

R. H. Whitbeck.

Some Influences of Geographic Environment upon Primitive Regions.

The religious beliefs of primitive peoples are necessarily influenced by the character of their environment. The early Norseman's heaven was a place of warmth and his hell a place of cold and darkness. Mohammed taught his desert followers that heaven is a garden with running water, trees and fruit. The American Indian believed heaven to be a happy hunting ground to which his dog, as well as himself, might go. To the Egyptian the Nile, overflowing and fertilizing his land, was a deity,—as rivers frequently are to agricultural peoples. The monsoon climate of India—differing radically from the arid climate of Bactria—gradually made over the mythology of the early Aryan invaders of India.

Geographic influence upon religious ideas is most marked among primitive peoples and declines in importance as their understanding of nature increases. The influence of geographical environment shows more in the writings of the Old Testament than in those of the New. Greek and Roman mythology reflect no dominant geographical influence partly because there was none so dominant as the Nile in Egypt, the desert in Arabia, or the monsoon in India—and partly because the Greeks and Romans had passed beyond the primitive stage of culture.

Explanation of Plate III

a Yānādi Family and Typical Home. The man holds a cleaver introduced by government for preparing firewood to send to Madras.

b A Village Group of the Yānādis. The earthen pots for cooking are brought to the island from Madras. The Yānādis have no potters.

PLATE III

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a

b

Explanation of Plate IV

A Yānādi wife getting a meal of boiled roots. On Srīharikota broken pots hold in place the boiling pot instead of stones as on the main land, and wood serves as fuel instead of dried cow dung.

PLATE IV

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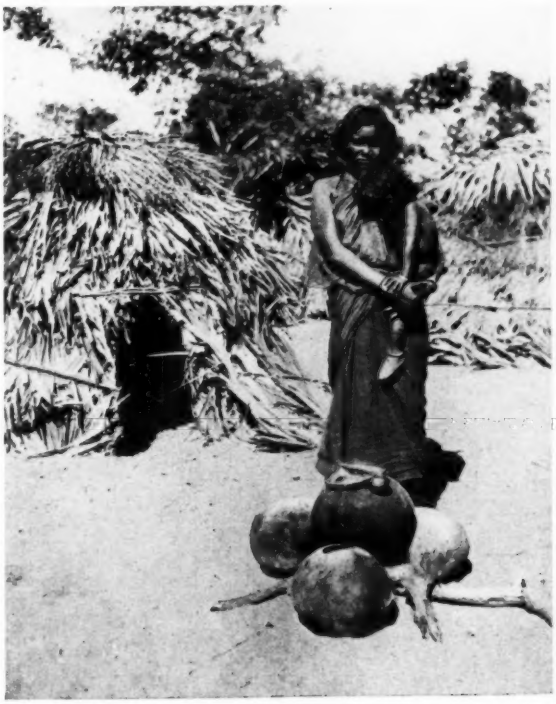

Explanation of Plate V

a A Yānādi making fire by friction. Although matches are now brought from Madras, this primitive method of kindling fire is commonly used, especially when the people are away from the village.

b A group of Yānādis beside their religious house with its sun shield. One is searching for parasites in the hair of another—a favorite pre-occupation of this simple folk.

PLATE V

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a

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Explanation of Plate VI

a Looking across the Buckingham Canal to the most important village on Srīharikota. The well-made houses have been put up for the Forest Range Offices and for a school. The rock, laterite from the mainland, is being brought here for government purposes.

b A Typical Well. The slight depth is of course due to the low altitude of the island. Such wells are the source of some of the diseases that spread among the people. See Plate VIIa.

PLATE VI

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a

b

Explanation of Plate VII

a The man with the enlarged leg is afflicted with elephantiasis arabum. The shallow open wells, Plate VIb, probably breed the mosquitoes that spread this disease. The boy in coat and turban at the left is the writer's interpreter.

b Gathering major forest products, mainly firewood, for the Madras market. A few Hindus are brought from the mainland to do the heaviest of this work. Yānādi women do the lightest work, Yānādi men do the rest.

PLATE VII

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a

b

Explanation of Plate VIII

a A train of cars loaded with firewood ready to start.

b Yānādis engaged in pushing wood cars from the jungle to the Buckingham Canal. The level surface of the island and their habit of running down game have well adapted them to this sort of work.

PLATE VIII

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a

b

Explanation of Plate IX

a A group of Yānādis who constitute the power of the government railroad on the island. They have succeeded where bullock teams failed.

b Going into the jungle of Srīharikota with the forest ranger and an interpreter on a man propelled car.

PLATE IX

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a

b

Explanation of Plate X

The bi-weekly arrival of the Yānādis who are employed by the government to collect minor forest products. The bags and baskets are supplied by the government. They contain soap nuts, nux vomica, rattans, honey, plate leaves, etc. The huge scales beyond tell what the products are worth. An average day's pay is four cents.

PLATE X

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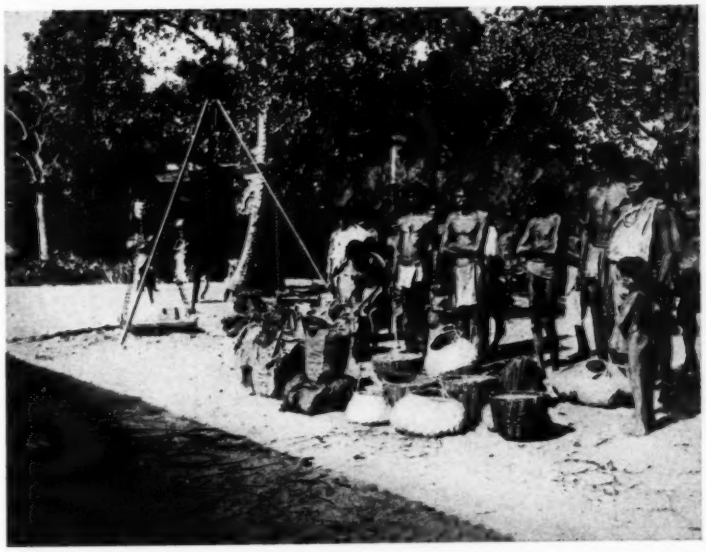

Explanation of Plate XI

a Canal boats under sail going south in the Buckingham Canal driven by the northeast trade winds. They are carrying jungle products to Madras from Srīharikota. Three pullers are shown drawing the writer's house boat against the wind.

b Bundles of plates of woven leaves from the Srīharikota jungle waiting shipment at a railway station on the east coast railroad. These plates are used as dinner plates.

PLATE XI

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a

b

Explanation of Plate XII

Yānādis on the mainland employed as "jutka" pullers and pushers. Here the railroad is ballasted with laterite and runs across the young coastal plain.

PLATE XII

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Explanation of Plate XIII

a Yānādis from Srīharikota living on the mainland. Their village is on the outskirts of a large town in which they work as night-watchmen. Here on the laterite soil which does not preserve the imprints of their feet they have a bad reputation.

b The mainland hut of the Yānādis is better made than his former one on the island since here he has laterite blocks and mud for building walls. Contrast with Plate III. Here, too, as shown in the foreground, laterite blocks make his fireplace instead of broken pots.

PLATE XIII

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a

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Explanation of Plate XIV

a Fragment of dolomitic limestone with desert rinds of calcite, which projects like a cornice through undercutting by driven sand. Libyan Desert.

b Limestone with brown color rind, but little hardened. Libyan Desert.

PLATE XIV

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a

b

Explanation of Plate XV

a Desert stone with protective rind, burnished by the sand blast. To the right a later cup-like depression where fragment has snapped off and new rind has since formed. Libyan Desert.

b Color rind (ferrite) but little protective in character. Libyan Desert.

PLATE XV

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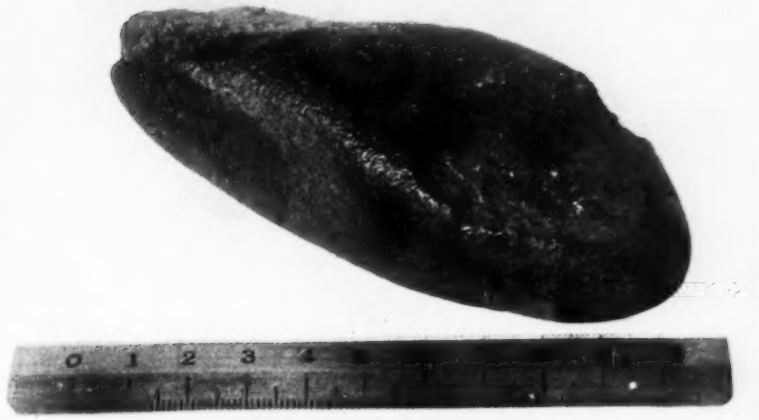

a

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Explanation of Plate XVI

Undercutting of thick adobe wall of the Roman fort El Der, showing the limited vertical range of effective sand erosion to be about one meter. Kharga Oasis.

PLATE XVI

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Explanation of Plate XVII

Armored surface of the desert, due to the process of deflation. Dj. Umm el Ghenneiem, Kharga Oasis.

PLATE XVII

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Explanation of Plate XVIII

a Adobe corner post to cemetery at Markaz el Sherikah Kharga Oasis. The post is composed of adobe blocks covered with adobe veneer, and shows the effect of less than a year's work by the cutting sand. The southern (lee) sides are not affected.

b *Island hill* of granite in advanced stage of spheroidal disintegration. Lower zone polished by sand blast, and upper zones exfoliated. Near Jebel Gerri station, Khartum district.

PLATE XVIII

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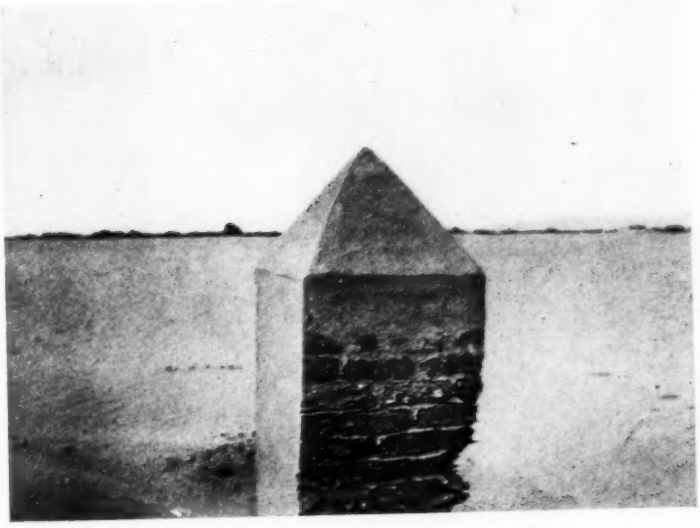

a

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Explanation of Plate XIX

Groups of ridges remaining as residuals of lake deposits carved by sand driven from the north (left) on floor of Kharga Oasis near Markaz el Sherikah.

PLATE XIX

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Explanation of Plate XX

Individual asymmetrical ridge of lake deposits showing the steep undercut north or windward side and the joint planes.

PLATE XX

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Explanation of Plate XXI

a Eocene limestone containing small silicious infusoria (*Operculina Libyca*) which turn the grains of driven sand and yield hoodoo like projections. J. Umm el Ghenneiem. Kharga Oasis.

b A similar specimen showing the shells capping the spines.

PLATE XXI

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a

b

Explanation of Plate XXII

a Sand and dust storm of June 6, 1906 (Huboub), sweeping over Khartum north, as seen from across the Blue Nile in Khartum (after G. N. Mohrig).

b Rhyolite with phenocrysts of feldspar left in relief through drilling away of groundmass by driven sand. Shabluka Hills, Khartum district.

PLATE XXII

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a

b

Explanation of Plate XXIII

a Eddies produced over a rough surface when drawn through water (after Ahlborn).

b Ruffled surface of limestone from action of driven sand. Libyan Desert west of Giza.

PLATE XXIII

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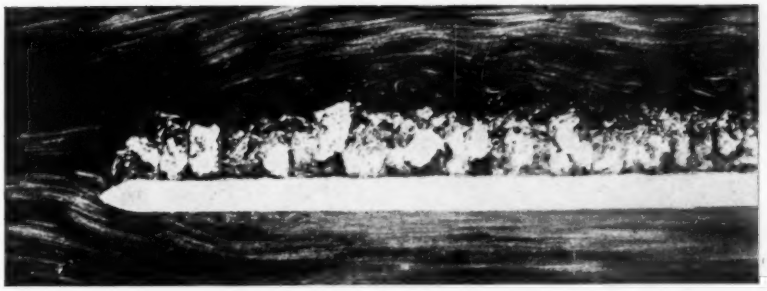

a

b

Explanation of Plate XXIV

Ruffled surface of limestone carved by driven sand. Libyan Desert west of Great Pyramids of Giza.

PLATE XXIV

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Explanation of Plate XXV

a Ruffled surface of sea simulated by the sand-cut surfaces of the limestone capping to the Libyan Hamada.

b Flow lines produced about a rigid plate drawn broadside through water (after Ahlborn).

PLATE XXV

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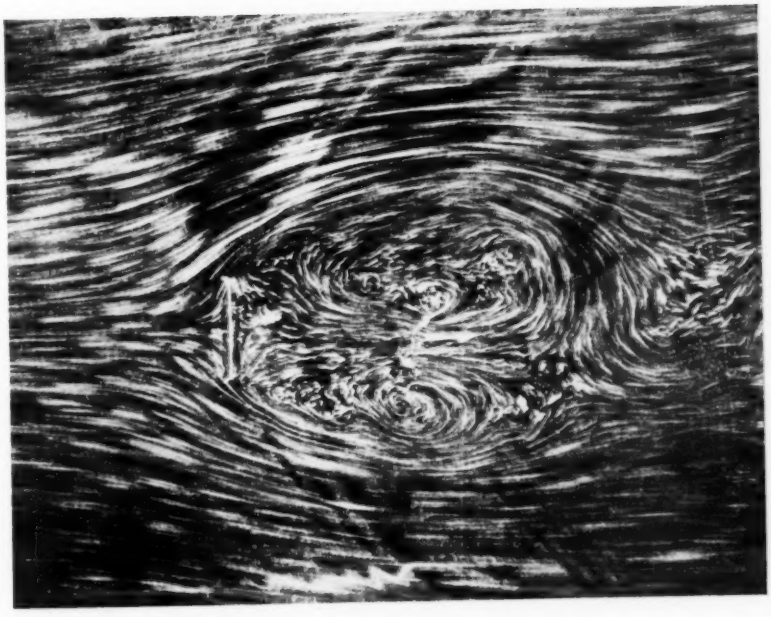
a



b

Explanation of Plate XXVI

a ***Island hill*** of granite in sand tenne, near Jebel Gerri station, Khartum district.

b Other island hills near Jebel Gerri station. Note desert vegetation.

PLATE XXVI

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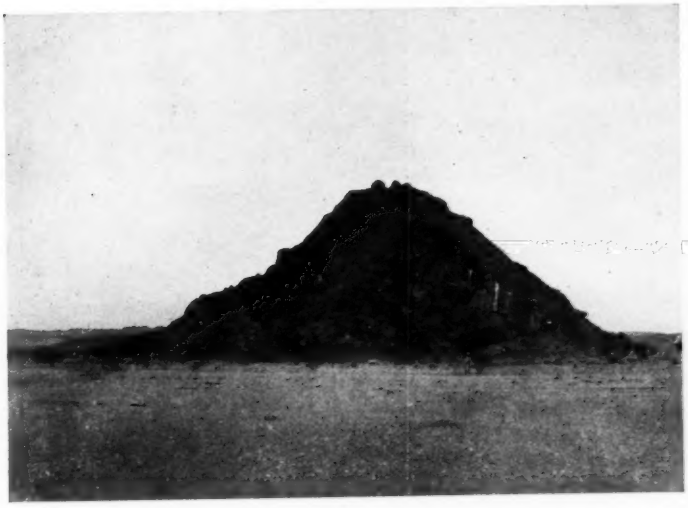

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